एनटीपीसी लिमिटेड
(भारत सरकार का उद्यम)
NTPC Limited
(A Govt. of India Enterprise)

**NTPC/KGN/EMG/EC-MOEF/HYC/2024** **Date: 15/05/2024**

**To**
**Additional Principal Chief Conservator of Forests (C),**
**Ministry of Environment, Forest and Climate Change,**
Regional Office (WZ), Kendriya Paryavaran Bhawan,
E-5 Arera Colony, Link Road-3,
Ravishankar Nagar,
**Bhopal-462016, Madhya Pradesh**
**Email id- rowz.bpl-mef@nic.in**

**Sub: Submission of 18th Half Yearly Environmental Clearance Compliance Report of Khargone Super Thermal Power Project (2x660 MW) at Village Selda & Dalchi, Khargone, Madhya Pradesh by NTPC Ltd.**

**EC Ref: J-13012/54/2010-1A. II (T), Dated-31.03.2015**

Dear Sir,

With reference to the above-mentioned subject matter and EC reference, please find enclosed the half yearly compliance status report to the stipulated conditions of Environmental Clearance for the period (**Oct'2023-Mar'2024**).

Submitted for your kind information and records please

Thanking you,

Yours sincerely,

**(Ashish Kumar Agarwal)**
**AGM (Ash & Envt. Mgmt.)**

**Encl.** as above

**Copy to:**

1. The Member Secretary,
**Central Pollution Control Board,**
Email-mscb.cpcb@nic.in

2. The Member Secretary,
**Madhya Pradesh Pollution Control Board,**
Email- ms-mppcb@mp.gov.in

# KHARGONE SUPER THERMAL POWER PROJECT (2x660 MW)

# HALF YEARLY COMPLIANCE REPORT OF ENVIRONMENTAL CLEARANCE CONDITIONS

## (For the period October'2023 - March'2024)

(EC Ref.-MOEF&CC Letter No. J- 13012/54/2010-IA. II (T) Dated 31st March 2015)

| A | MOEF & CC- Specific Conditions: | Status as on Implementation |
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| i | Coal transportation shall be by Rail only. An additional EIA shall be carried out and an EMP shall be prepared for laying down the rail line and alternate mode of transportation, in case rail line gets delayed. The EIA/EMP shall be submitted to the Ministry within one year of issuing the EC. | Complied<br>Rail network for NTPC-Khargone has been established and entire coal is being transported by railway route only. |
| ii | The Sulphur and Ash content of coal shall not exceed 0.5% and 43% respectively. In case of variation of quality at any point of time, fresh reference shall be made to the Ministry for suitable amendments in the environmental clearance. | Compliance assured<br>MOEF&CC Vide Office Memorandum dated 11.11.2020 has modified this condition. The project proponent has to only inform to the Regional Office of MOEF&CC regarding the change in coal source and quality. |
| iii | Latest authenticated satellite imagery shall be submitted to the Regional Office of the Ministry on an annual basis to monitor the environmental alterations of the area. | Complied<br>Satellite imagery of NTPC-Khargone and its vicinity land area is regularly submitted to the Regional Office of the MOEF&CC annually. Satellite imagery of NTPC-Khargone for the year 2023-24 was submitted along with last Half-yearly compliance report on 28.11.2023 |
| iv | Vision document specifying prospective plan for the site shall be formulated and submitted to the Regional Office of the Ministry within six months. | Complied<br>Vision document specifying prospective plan of the project was submitted to the Regional Office of the MOEF&CC at Bhopal vide NTPC letter dated 07.09.2015. |
| v | Harnessing solar power within the premises of the plant particularly at available roof tops shall be carried out and status of implementation including actual generation of solar power shall be submitted along with half yearly monitoring report. | Complied<br>For harnessing solar power, Roof-top and Land mounted solar power plants of total capacity of 1654 KW installed & operational within plant & township premises<br>Actual generation of solar power during the FY 2023-24 up to Mar'24 is 2076663.48 KWH. |
| vi | One twin flue stack of 275 m height shall be provided with continuous on-line monitoring system of $SO_x$, $NO_x$ and **PM2.5 & *PM10.* Exit velocity of flue gases shall not be less than 22 m/sec. In addition to the regular parameters, Mercury | Complied<br>One twin-flue stack of 275-meter height provided for both units. Continuous online emission monitoring system (CEMS) facilities also provided for monitoring of SO2, NOx and PM. |

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| | emission form stack shall also be monitored of six-monthly basis.<br>*As per EC Amendment letter by MOEF & CC dated 22.01.2022 the condition is modified as "*PM in stack emission" in place of PM2.5 & PM10* | Separate stacks of height 150 m also provided for FGD units of respective Unit-1 & Unit-2. Continuous online emission monitoring system (CEMS) facilities also provided for monitoring of SO2, NOx and PM at FGD Stacks. Exit velocity of flue gases being maintained above 22 m/sec.<br>Mercury emission form stack also being monitored periodically.<br>Please refer Annexure-1, for Mercury emission report from stack for the reporting period. |
| vii | High Efficiency Electrostatic Precipitators (ESPs) shall be installed to ensure that particulate emission does not exceed 50 mg/Nm$^3$. Adequate dust extraction system such as cyclones/bag filters and water spray system to control fugitive emissions in dusty areas such as in coal handling and ash handling points, transfer areas and other vulnerable dusty areas shall be provided. | Complied<br>High Efficiency Electrostatic Precipitators (ESPs) designed for a guaranteed efficiency of 99.97% provided and operational. The particulate emissions are controlled and maintained within prescribed norms of 30 mg/Nm$^3$ in compliance to MOEF&CC notification dated 07.12.2015, for revised emission norms for TPPs. Adequate dust extraction system and water spray system also provided to control fugitive emissions at coal handling, coal stockyard, ash handling area, transfer points and other vulnerable dusty areas.<br>Please refer Annexure-1, for Particulate Matter emission from stack for the reporting period. |
| viii | COC of at least 5.0 shall be adopted. | Compliance assured<br>Closed cycle cooling water re-circulation system is implemented to meet prescribed COC, for the conservation/optimization of water requirement. Annual CoC for FY:2023-24 is 5.07. |
| ix | Monitoring of surface water quantity and quality shall be conducted regularly and records shall be maintained. The monitoring points shall be located between the plant and drainage in the direction of flow of ground water and records shall be maintained. The monitored data shall be submitted to the Ministry every six months. | Complied<br>Regular monitoring of surface water being carried out through MOEF&CC accredited and NABL certified third party laboratory. Records are being maintained and monitoring reports regularly submitted to Regional Office of the MOEF&CC at every six months.<br>Please refer Annexure-1 for Surface water reports for the reporting period. |
| x | Monitoring for heavy metals in ground water in the vicinity of plant shall also be undertaken and monitoring report shall be submitted to the ministry every six months. | Complied<br>Regular monitoring of heavy metals in ground water are being carried out through MOEF&CC accredited and NABL certified third party laboratory. Monitoring reports |

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| | | regularly submitted to Regional Office of the MOEF&CC at every six months.<br>Please refer Annexure-1 for Heavy metals in ground water reports for the reporting period. |
| xi | A well-designed rainwater harvesting system shall be put in place within six months, which shall comprise of rainwater collection from the built up and open area in the plant premises and records shall be kept for the quantity of water harvested every year and its use. | Complied<br>Well-designed, CGWA approved rainwater harvesting system, comprise of rainwater collection from the built-up area, open area & storm water of the capacity 0.36 MCM is installed at plant premises. Records for the harvested quantity of water every year being maintained. Rainwater harvested is fully used to recharge the ground water through recharge pits as per the approved scheme. |
| xii | No water bodies including natural drainage system in the area shall be disturbed due to activities associated with the setting up/ operation of the power plant. | Complied<br>No water body including natural drainage system of the area have been disturbed. |
| xiii | Hydro geology of the area shall be reviewed annually through an institute/ organization of repute to assess impact of surface water and ground water (especially around ash dyke). In case, any deterioration is observed specific mitigation measures shall be undertaken immediately. Reports/data of water quality shall be submitted to the Regional Office of the Ministry every six months. | Complied<br>Baseline Hydro-geological study was carried out through National Institute of Hydrology (NIH), Roorkee. Annual review of hydro geology to assess impact of surface water and ground water (especially around ash dyke) has been also carried out through an institute/ organization of repute. Please refer Annexure-2 for the Final report of hydrogeology review study submitted by M/s IIT-Roorkee for year 2023-24.<br>Reports of surface and ground water quality are regularly submitted to Regional Office of the MOEF&CC at every six months.<br>Please refer Annexure-1 for Surface & Ground water quality reports for the reporting period. |
| xiv | Wastewater generated from the plant shall be treated before discharge to comply with the standards prescribed by the SPCB/CPCB. | Complied<br>Effluent Management Scheme has been designed and implemented with the objective to treat the entire wastewater as per the prescribed statutory standards of MPPCB/CPCB. It is to be submitted that during normal course of operations, zero liquid discharge being adopted based on maximum recycle/reuse of wastewater for various plant usage. |
| xv | Additional soil for leveling of the proposed site, if require shall be taken from within the sites (to the extent | Complied<br>For leveling of site all additional soil being taken from within the sites only (to the extent |

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| | possible) so that natural drainage system of the area is protected. | possible) with all necessary precautions to protect natural drainage system of the area. |
| xvi | Fly ash shall be collected in dry from and storage facility (silos) shall be provided. Un-utilized fly ash shall be disposed-off in the ash pond in the form of slurry. Mercury and other heavy metals (As, Hg, Cr, Pb etc.) will be monitored in the effluents emanating from the ash pond and in the bottom ash also. No ash shall be disposed-off in low-lying area. | Complied<br>An ash management & disposal scheme is implemented consisting of dry ash extraction system (DAES) for dry collection of fly ash with adequate storage facility (silos) to supply ash to entrepreneurs for utilization.<br><br>Un-utilized ash is being safely disposed in the ash pond in the form of slurry. Two different systems are being provided for ash disposal: Conventional wet slurry disposal system with ash water re-circulation for bottom ash and High Concentration Slurry Disposal (HCSD) system for fly ash disposal.<br>Mercury & other heavy metals (As, Hg, Cr, Pb etc.) are regularly monitored in the ash water emanating from ash pond and in the bottom ash.<br>No ash is being disposed-off in low-lying area at present. Prior permission shall be obtained for ash disposal in low-lying area.<br>Please refer **Annexure-1** for Mercury & Heavy metals report in ash water & bottom ash for the reporting period. |
| xvii | Fugitive emission of fly ash (dry or wet) shall be controlled such that no agricultural or non-agricultural land is affected. Damage to any land shall be mitigated and suitable compensation shall be provided in consultation with the local Panchayat. | Complied & Noted<br>Dust suppression system comprising of water spray nozzles are provided all around the ash ponds for effective control of fugitive emission of fly ash. Further, closed trucks/ bulkers/covered vehicle/closed BLC container railway wagons are being used for transportation of fly ash to avoid fugitive dust emission. |
| xviii | Ash pond shall be line with HDPE/LDPE lining or any other suitable impermeable media so that no leaching takes place at any point of time. Adequate safety measures shall also be implemented to protect the ash dyke from getting breached. | Complied<br>To avoid any leaching and ground water contamination from ash slurry, suitable impermeable media lining provided in ash dyke. Bottom ash lagoons are lined with suitable impermeable media i.e., bentonite blended clay in order to achieve the required permeability. In HSCD lagoon the disposed layers of ash are solidified and there is very less free water. Overflow lagoon of ash dyke is also lined with impervious thick liner of 300 mm at bottom.<br>The structure of ash dykes has been designed, constructed, and being operated as per state- |

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| | | of-the-art engineering practices for the design and construction of earth dams with adequate factor of safety. Ash dyke being constructed considering the seismic parameters in its design. Regular monitoring and inspection of ash dykes and an emergency response system will ensure that there are no risks of failure as apprehended.<br>Further, in compliance to MOEF&CC Gazette Notification dtd. 31.12.2021, an annual certification of ash dyke also done for the year 2023-24 as per guidelines issued by Central Pollution Control (CPCB) & Central Electricity Authority (CEA). Certification report already submitted to the CPCB & MPPCB on 21.03.2024 |
| xix | A long-term study of radioactivity and heavy metals contents of coal to be used shall be carried out through a reputed institute and results shall be analyzed every two years and shall be reported to the Ministry along with the monitoring reports. Thereafter, mechanism for * *in-built continuous monitoring* for radioactivity and heavy metals in coal and fly ash (including bottom ash) shall be put in place.<br>*As per EC Amendment letter by MOEF & CC dated 22.01.2022 the condition is modified as *"regular periodical monitoring"* in place of in-built continuous monitoring. | Complied<br>Annually, monitoring of Radioactivity content of coal has been carried out through Board of Radiation & Isotope Technology (BRIT) under Dept. of Atomic Energy, Govt. of India. Reports of Radioactivity content analysis in coal & ash samples are regularly submitted along with Half-yearly compliance report.<br>Please refer Annexure-3 for radioactivity content report in coal & ash samples for the year 2023-24.<br>Further, Regular periodical monitoring of Heavy metals content of coal has been also carried out through MOEF&CC accredited and NABL certified third party laboratory.<br>Reports are regularly submitted to the Regional office of MOEF&CC along with half-yearly compliance reports.<br>Please refer Annexure-1 for Heavy metals content report for the reporting period. |
| xx | Green Belt of least 50m width consisting of three tiers of plantations of native species around the plant shall be raised. Wherever 50m width is not feasible, an adequate justification shall be submitted to the Ministry and appropriate width not less than 20m shall be planted. Tree density shall not be less than 2500 per ha with survival rate not less than 80%. | Compliance assured<br>Green belt development/tree plantation is being carried out at all available spaces inside and outside the plant and township premises. Further tree plantation being taken up at external forest land and Govt. land to enhance the green cover. Avenue plantation along the approach roads and ash dyke also being taken up.<br>Cumulative 4.35 lakhs tree have been planted till date at inside and outside the NTPC-Khargone premises through Govt. agencies i.e. Madhya Pradesh Rajya Van Vikas Nigam Ltd. |

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| | | and Rural Engineering Services depts. under Govt. of Madhya Pradesh. |
| xxi | Green belt shall also be developed around the ash pond over and above the Green Belt around the plant boundary. | Compliance assured<br>Tree plantation at the vicinity of ash pond sites and along peripheral roads is being planted. |
| xxii | CSR schemes identified based on need-based assessment shall be implemented in consultation with the village Panchayat and the District Administration starting from the development of project itself. As part of CSR, prior identification of local employable youth the eventual employment in the project after imparting relevant training shall be also undertaken. Company shall provide separate budget for community development activities and income generation programs. | Compliance assured<br>NTPC Khargone was executing development schemes under its Community Development program earlier. Now, NTPC Khargone has entered CSR Phase from FY 2024-25.<br>The said Community Development activities are carried out as envisaged in the approved R&R Plan for the NTPC Khargone project.<br><br>Out of 52.31 Cr. total approved budget of Community Development activities, an amount of 37.34 Cr has been utilized, while the work of balance amount is under progress. Please refer to Annexure-4 for the list of Community Development activities undertaken in during the reporting period |
| xxiii | For periodic monitoring of CSR activities, a CSR Committee or a Social Audit committee or a suitable credible external agency shall be appointed. CSR activities shall also be evaluated by an independent external agency. This evaluation shall be both concurrent (every six months) and final. | Compliance assured<br>The Need Assessment Survey (NAS) and the Social Impact Evaluation (SIE) Study has been completed and the reports has been submitted for Khargone Station. |
| xxiv | An Environmental Cell comprising of at least one expert in environmental science/ engineering, ecology, occupational health, and social science shall be created preferably at the project site itself and shall be headed by an officer of appropriated seniority and qualification. It shall be ensured that the Head of the cell shall directly report to the Head of the Plant who would be accountable for implementation of environmental regulations and social impact improvement/ mitigation measures. | Complied<br>An Environment Management Group (EMG) with qualified team, headed by AGM (Ash & Envt. Mgmt.) is already functional at the Khargone project site.<br>EMG is responsible for implementation and compliance of environmental stipulations and ensure mitigation measures. |
| **B** | **MOEF & CC- General Conditions:** | **Status as on Implementation** |
| i | Space for FGD shall be provided for future installation, if required. | Complied<br>Adequate space for FGD was kept and utilized for FGD installation. |

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| | | FGD installation completed and available for both Units. Dates of Commercial Operation for FGD:Unit-1 and FGD:Unit-2 are 25.05.2023 & 14.09.2023 respectively. |
| ii | The treated effluents conforming to the prescribed standards under Environment (Protection) Act 1986 only shall be re-circulated and reused within the plant. Arrangements shall be made that effluents and storm water do not get mixed. | Complied<br>Effluent treatment system comprising of effluent treatment plant, neutralization pit, oil & grease separator, settling ponds and cooling towers etc. provided to treat effluents conforming the prescribed standards.<br>An integrated scheme for treatment, recycle and reuse of effluents is implemented. Cooling water blow down is reused in CHP, AHP, FGD and firefighting. Ash water effluent recirculation also being provided for reuse in ash handling purpose. Provision also made for treatment, recirculation & reuse of effluents from coal handling plant. Further, Zero Liquid Discharge (ZLD) scheme is implemented for recycle & reuse of wastewater generated, thereby reducing, and optimizing the quantities of water requirement.<br>Independent plant effluent drainage system provided to ensure that plant effluents do not mix with storm water drainage. |
| iii | A sewage treatment plant shall be provided (as applicable) and the treated sewage shall be used for raising greenbelt/plantation. | Complied<br>Sewage treatment plant (STP) provided to treat sewage effluents emanating from plant and township.<br>The STP treated water, conforming to prescribed standards utilized for plantation & raising greenbelt/plantation. |
| iv | Adequate safety measures shall be provided in the plant area to check/ minimize spontaneous fires in coal yard, especially during summer season. Copy of these measures with full details along with location, plant layout etc. as and when finalized, shall be submitted to the ministry as well as to the regional office of the Ministry. | Complied<br>Adequate no. of Fire Spray & Hydrant system covering the entire power station including all the auxiliaries and buildings in the plant area is provided as per fire safety requirements. The system is adequately equipped with piping, hydrants, valves, instrumentation, hoses, nozzles, hose boxes/stations etc.<br>Copy of safety measures details already submitted along with Half-yearly compliance dated 22.04.2019. |

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| v | Separate storage facilities for auxiliary liquid fuel such as LDO/HFO/LSHS shall be made in the plant area in consultation with Department of Explosives, Nagpur. Sulphur content in the liquid fuel will not exceed 0.5%. Provisions of the Manufacture, Storage and Import of Hazardous Chemical Rules and the Chemical Accidents (Emergency Planning, Preparedness and Response) Rules, 1996 shall be applicable as per the quantity stored. Disaster Management System shall be established as per the Disaster Management Plan to meet any eventuality in case of an accident taking place due to storage of oil. | Complied<br>Storage facility designed and provided for LDO as auxiliary liquid fuel, inside plant area conforming to the adequate safety standard and where risk is minimal. Necessary license has been obtained from Department of Explosives. Sulphur content in LDO being ensured within limits.<br>A detailed Disaster Management Plan & Risk assessment including fire and explosion issues is prepared and finalized in consultation with Department of Explosives. Regular mock drills being conducted as per plan in order to address any eventuality in case of an accident. |
| vi | First Aid and sanitation arrangements shall be made for the drivers and other contract workers during construction phase. | Complied<br>Adequate arrangements for first aid, health & safety, and sanitation for workers have been provided and compliance ensured. |
| vii | Noise levels from turbines in work zone shall be limited to 85 dB (A) from source. For people working in the high noise area, requisite personal protective equipment like earplugs/earmuffs etc. shall be provided. Workers engaged in noisy areas such as turbine area, air compressors etc. shall be periodically examined to maintain audiometric record and for treatment for any hearing loss including shifting to non-noisy/less noisy areas. | Complied<br>Design specification for the equipments has been made to comply with the stipulations. Noise levels from turbines in work zone being maintained within prescribed limits of 85 dB (A) from source.<br>Personal Protective Equipment (PPE's) are also being provided to personnel working in high noise areas. Workers of turbine generator area, compressor area and other high noise area being provided with appropriate ear protection devices.<br>Periodic health examination of workers also being done as stipulated. |
| viii | Regular monitoring of ambient air ground level concentration of $SO_2$, $NO_x$, $PM_{2.5}$ & $PM_{10}$ and Hg shall be carried out in the impact zone of the project and record shall be maintained. In case these levels exceed the prescribed limits, necessary control measures shall be taken immediately. The location of the monitoring stations and frequency of monitoring shall be decided in consultation with SPCB. Monitoring reports shall be submitted to the Regional Office of this Ministry every six months. The data shall also be uploaded on the website of the company. | Complied<br>Three nos. of CAAQMS stations have been installed at main-plant and township locations in consultation with MPPCB for regular monitoring of ambient air quality and record is maintained. Adequate control measures have also been ensured to control the exceedance if any. Additionally, one CAAQMS station is also installed at Khargone city as per directions from MPPCB.<br>Regular monitoring of ambient air quality also carried out periodically through MOEF&CC accredited and NABL certified third party laboratory. Reports are regularly submitted to the Regional Office of MOEF&CC. Please refer |

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| | | Annexure-1 for ambient air quality reports for the reporting period. Online ambient air monitoring data also being uploaded on NTPC-Khargone Intranet webpage. |
| ix | Fly Ash generated shall be utilized 100% from the 4th year of operation of the power plant. Status of fly ash utilization shall be reported each year to the Regional Office of the Ministry. | Complied<br>Ash utilization plan has been prepared and all efforts are being made to achieve the targets in compliance to MOEF&CC, Fly ash Gazette Notification dated 03.11.2009, 31.12.2021 and its amendments, notifications thereafter. Annual compliance status of fly ash utilization being submitted regularly to the Regional office of MOEF&CC. Please refer Annexure-5 for Annual compliance report (ACR) of Ash Utilization for the FY 2023-24. |
| x | Provision shall be made for the housing of construction labor (as applicable) within the site with all necessary infrastructures and facilities such as fuel for cooking, mobile toilets, mobile STP, safe drinking water, medical health care, crèche etc. The housing may be in the form of temporary structure to be removed after the completion of the project. | Compliance assured<br>Labor colony with necessary infrastructure facilities had been provided for construction labor during construction phase and was kept under the scope of EPC contractor. Whereas NTPC ensures effective compliance of the said stipulations. |
| xi | The project proponent shall advertise in at least two local newspapers widely circulated in the region around the project, one of which shall be in the vernacular language of the locality concerned within seven days from the date of receipt of this clearance letter, informing that the project has been accorded environmental clearance and copies of clearance letter are available with the State Pollution Control Board/Committee and may also be see at Website of the Ministry of Environment and Forests at http://envfor.nic.in. | Complied<br>The information of Environmental Clearance was published in two newspapers widely circulated in the region are-<br>1. Hindustan Times (English) on dated 04.04.2015.<br>and<br>2. Nai-Dunia (Hindi) on dated 04.04.2015. |
| xii | A copy of the clearance letter shall be sent by the proponent to concerned Panchayat, Zila Parisad/ Municipal Corporation, urban local body and the Local NGO, if any, from whom suggestions/representations, if any, received while processing the proposal. The clearance letter shall also be put on the website of the Company by the proponent. | Complied<br>Copy of clearance letter were sent vide our letter dated 06.04.2015 to Sarpanch of village Panchayat of Selda & Dalchi village, CEO of Khargone Distt & CEO of Khargone Municipal Corporation. The Environmental Clearance is uploaded on the NTPC Ltd. website. |

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| xiii | The proponent shall upload the status of compliance of the stipulated environmental clearance conditions, including results of monitored data on their website and shall update the same every six months. It shall simultaneously be sent to the Regional Office of MOEF, the respective Zonal Office of CPCB and the SPCB. | Complied<br>The latest status report of Compliance to the stipulated Environmental Clearance (EC) conditions is regularly uploaded on NTPC website. Compliance status report also submitted to the Regional Office of the MOEF&CC and offices of CPCB & MPPCB regularly at every six months. |
| v | The criteria pollutant levels namely; SPM, RSPM ($PM_{2.5}$ & $PM_{10}$), $SO_2$, $NO_x$ (ambient levels as well as stack emissions) shall be displayed at a convenient location near the main gate of the company in the public domain. | Complied<br>The criteria pollutant levels as prescribed, for ambient air as well as stack emissions are displayed at a convenient location near the main gate of the company in the public domain. |
| xv | The environment statement for each financial year ending 31st March in Form-V as prescribed under the Environment (Protection) Rules, 1986, as amended subsequently, shall be submitted by the project proponent to the concerned State Pollution Control Board. The same shall also be uploaded on the website of the company along with the status of compliance of environmental clearance conditions and shall also be sent to the respective Regional Offices of the Ministry by e-mail. | Complied<br>Environment Statement for each financial year ending 31st March in Form-V has been regularly submitted to the M.P. Pollution Control Board & Regional Office of the MOEF&CC timely by September every year. Environmental Clearance along with annual environment statement is regularly updated on the NTPC website.<br>Please refer Annexure-6 for Annual Environment Statement (Form-V) of the FY 2023-24. |
| xvi | The project proponent shall submit six monthly reports on the status of the implementations of the stipulated environmental safeguards to the Ministry of Environment and Forests, its Regional Office, Central Pollution Control Board and State Pollution Control Board. The project proponent shall upload the status of compliance of the environment of the environmental clearance conditions on their website and update the same every six months and simultaneously send the same by email to the Regional office, Ministry of Environment and Forests. | Complied<br>Six monthly compliance status report of EC conditions regularly submitted to the Regional Office of MOEF&CC, CPCB & MPPCB. Reports are also uploaded on the NTPC website periodically. |
| xvii | Regional office of the Ministry of Environment & Forests will monitor the implementation of the stipulated conditions. A complete set of documents including Environmental Impact Assessment Report and Environment Management plan along with the | Complied<br>A complete set of documents including Environmental Impact Assessment (EIA) Report and Environment Management Plan (EMP) along with the additional information/clarifications was already |

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| | additional information submitted from time to time shall be forwarded to the Regional Office for their use during monitoring. | submitted to Regional Office (Western Zone) of the MOEF&CC at Bhopal on 05.10.2015 |
| xviii | The details of the funds along with item-wise break-up of Rs.1421.2 crores allocated for implementation of environmental protection measures shall be submitted to the Ministry. This cost shall be included as part of the project cost. The funds earmarked for the environment protection measures shall not be diverted for other purposes and year-wise expenditure shall be reported to the Ministry. | Compliance assured<br>The requisite funds for environmental mitigation measures have been included in the project cost. Financial provision stipulated towards environmental mitigate measures shall not be diverted for other purposes. |
| xix | The project authorities shall inform the Regional Office as well as the Ministry regarding the date of financial closure and final approval of the project by the concerned authorities and the dates of start of land development work and commissioning of plant. | Complied<br>Site leveling/ Land development work started on July 17th, 2015.<br>Trial operation commissioning of Unit#1 (660 MW) achieved on 29/09/2019 and Commercial Date of Operation (COD) declared from 01/02/2020.<br>Trial operation commissioning of Unit#2 (660 MW) achieved on 24/03/2020 and Commercial Date of Operation (COD) declared from 04/04/2020. |
| xx | Full cooperation shall be extended to the Scientists/officers from the Ministry / Regional Office of the Ministry/ CPCB /SPCB who would be monitoring the compliance of environmental status. | Noted |
| 5 | The Ministry reserves the right to revoke the clearance if conditions stipulated are not implemented to the satisfaction. The Ministry may also impose additional environmental conditions or modify the existing ones, if necessary. | Noted |
| 6 | The environmental clearance accorded shall be valid for a period of 5 years from the date of issue of this letter to start operation of the power plant. | Noted |
| 7 | Concealing factual data or submission of false/fabricated data and failure to comply with any of the conditions mentioned above may result in withdrawal of this clearance and attract action under the provisions of Environment (Protection) Act, 1986. | Noted |

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| 8 | In case of any deviation or alteration in the project proposed including coal transportation system from those submitted to this Ministry for clearance, a fresh reference should be made to the Ministry to assess the adequacy of the condition(s) imposed and to add additional environmental protection measures required, if any. | Noted |
| 9 | The above stipulations would be enforced among others under the water (prevention and Control of pollution) Act, 1974, the Air (Prevention and Control of Pollution) Act,1981, the Environment (Protection) Act,1986 and rules there under, Hazardous Wastes (Management, Handling & Trans-boundary Movement) Rules, 2008 and its amendments, the public Liability Insurance Act, 1991 and its amendments. | Noted |
| 10 | Any appeal against this Environmental Clearance shall lie with the National Green Tribunal, if preferred, within 30 days as prescribed under Section 16 of the National Green Tribunal Act, 2010. | Noted |

## COMPLIANCE REPORT OF ADDITIONAL CONDITIONS

*(EC Amendment vide MOEF&CC Letter Dated 22nd August 2019)*

| **A** | **MOEF & CC- Specific Conditions:** | **Status of Implementation** |
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| 1 | While commissioning the proposed project, the compliance of revised emission norms vide Notification dated 07.12.2015 for the parameters PM: 30 mg/Nm3; S02: 100 mg/Nm3; NOx: 100 mg/Nm3 and Hg: 0.03 mg/Nm3 shall be achieved along with specific water consumption as per the notification vide dated 28.06.2018. The FGD System, NOx control measures such as SCR/ SCNR/ DeNOx burners shall be installed to achieve the revised emission norms. | Compliance assured<br>NTPC-Khargone ensures compliance to all standards as stipulated in the revised emission norms vide referred MOEF&CC Notification dated 07.12.2015 and its amendments thereafter.<br>Particulate Matter (PM) emissions from boiler stacks being controlled within prescribed new emission norms (30 mg/Nm3)<br>FGD plants installed, commissioned & available in both Unit-1 & Unit-2 for SO2 emission control within prescribed new emission norms (100 mg/Nm3)<br>Low NOx burners with Over Fire Air (OFA) combustion system also provided in both Units, for NOx emission control.<br>Specific water consumption (SWC) being maintained within prescribed norms of 3.0 m3/mwhr as per the MOEF&CC notification |

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| | | dated 28.06.2018. SWC for the FY: 2023-24 is 2.48 m3/mwh.<br>Whereas CPCB-Task Force vide his letter dtd. 13.12.2021, for the categorization of TPPs in line with MOEF&CC Notification dated 31/03/2021, has classified both units of NTPC-Khargone under Category-C. Accordingly, as per referred notification above revised emission norms compliance shall be ensured by Dec'2024 for Category-C power plants including NTPC-Khargone. Whereas, as per MOEF&CC Notification dtd.05.09.2022, SO2 emissions timeline for compliance (Non-retiring units) is extended up to Dec'2026 for Category-C TPPs includes both units for NTPC-Khargone. |
| 2 | The status of installation of FGD and De-NOx/SCR/SNCR control systems to comply with new emission norms for both units shall be submitted. | Complied assured<br>For SO2 emission control, installation of FGD plant package was awarded to M/s L&T for both units. Erection & Commissioning of FGD plants completed and available for both Units. Dates of Commercial Operation for FGD:Unit-1 and FGD:Unit-2 are 25.05.2023 & 08.12.2023 respectively.<br>Status of installation of FGD control system is regularly submitted to the Regional Office of the MOEF&CC at every six months along with Half-yearly EC compliance report.<br>For NOx emission control, Low NOx Burners with Over Fire Air (OFA) combustion control system (air/fuel ratio optimization around the burner) is provided in both units. However, the matter for NOx emission compliance by TPPs commissioned after 2017 is under subjudice at Hon'ble Supreme Court.<br>Please refer Annexure-7 for FGD installation status report for the reporting period. |
| 3 | The detailed progress report of construction of proposed project shall be submitted to the Ministry and its Regional Office along with six monthly compliance report till both units are commissioned. | Complied<br>Both Unit#1 and Unit#2 were commissioned and under commercial operation from 01/02/2020 & 04/04/2020 respectively. |
| 4 | As per the Revised Tariff Policy notified of Ministry of Power issued vide dated 28.01.2016, project proponent shall | Noted & Compliance assured |

| | | |
|---|---|---|
| | explore the use of treated sewage water from the Sewage Treatment Plant of Municipality/ local bodies/ similar organization located within 50 km radius of the proposed power project to minimize the water drawl from surface water bodies. The details of Sewage Treatment Plants located within 50 km radius along with the capacities shall be submitted. | |
| 5 | Daily quantity of (Average, minimum and maximum) fresh water withdrawn from Narmada River at Omkareshwar Dam for the plant purpose shall be submitted along with six monthly compliance report. | Noted & Compliance assured<br>Please refer Annexure-8 for Fresh water withdrawn data for the reporting period. |

## COMPLIANCE REPORT OF ADDITIONAL CONDITIONS

*(EC Amendment vide MOEF&CC Letter Dated 22nd January 2022)*

| **A** | **MOEF & CC- Specific Conditions:** | **Status of Implementation** |
|---|---|---|
| i | 24x7 online Continuous monitoring system for ambient air quality parameters SOx, NOx and PM shall be established with connected server to CPCB and SPCB. | Complied<br>Realtime Continuous Ambient Air Quality Monitoring Stations (CAAQMS) have been installed. Further, 24x7 online connectivity of the same also provided up to the MPPCB and CPCB. |

**ANNEXURE-1**

# Environment Monitoring Report

**Industry:** NTPC Ltd. Khargone Super Thermal Power Project
**Period:** October'2023 to March'2024
**Laboratory** M/s Hubert Enviro Care Systems Pvt. Ltd
(MOEF&CC Accredited and NABL Lab)/Online CEMS

## Stack Emission Monitoring Report

For the period of Oct'23-Mar'24

| Stack attached to Boiler | Parameter | PM | SO2 | NOx | Hg |
|---|---|---|---|---|---|
| | Unit | mg/Nm3 | mg/Nm3 | mg/Nm3 | mg/Nm3 |
| Unit-1 | Avg | **25.2** | **1429.0** | **290.4** | **<0.01** |
| | Min | 20.9 | 1108.0 | 259.0 | <0.01 |
| | Max | 28.5 | 1268.0 | 301.7 | <0.01 |
| Unit-2 | Avg | **25.7** | **1384.8** | **283.1** | **<0.01** |
| | Min | 22.5 | 1096.0 | 265.8 | <0.01 |
| | Max | 29.2 | 1316.0 | 294.0 | <0.01 |

| Stack attached to FGD | Parameter | PM | SO2 | NOx | Hg |
|---|---|---|---|---|---|
| | Unit | mg/Nm3 | mg/Nm3 | mg/Nm3 | mg/Nm3 |
| FGD-1: Unit-1 | Avg | **3.6** | **38.5** | **229.2** | **<0.01** |
| | Min | 0.6 | 10.7 | 134.6 | <0.01 |
| | Max | 7.0 | 84.6 | 254.1 | <0.01 |
| FGD-2: Unit-2 | Avg | **5.7** | **30.6** | **175.4** | **<0.01** |
| | Min | 2.2 | 7.8 | 134.0 | <0.01 |
| | Max | 14.4 | 61.3 | 214.8 | <0.01 |

## Ambient Air Monitoring Report

For the period of Oct'23-Mar'24

| Location | Nr. Main Gate/Service Building | | | | |
|---|---|---|---|---|---|
| Parameter | S0x | NOx | PM10 | PM2.5 | CO |
| Unit | ug/m3 | ug/m3 | ug/m3 | ug/m3 | mg/m3 |
| Avg | 11.4 | 22.0 | 60.6 | 34.0 | <0.5 |
| Min | 10.5 | 19.8 | 47.3 | 24.9 | <0.5 |
| Max | 12.8 | 24.9 | 77.0 | 48.6 | <0.5 |
| Location | Nr. DM Plant | | | | |
| Parameter | S0x | NOx | PM10 | PM2.5 | CO |
| Unit | ug/m3 | ug/m3 | ug/m3 | ug/m3 | mg/m3 |
| Avg | 12.3 | 22.6 | 65.1 | 33.4 | <0.5 |
| Min | 9.6 | 18.2 | 49.2 | 24.6 | <0.5 |
| Max | 15.0 | 25.1 | 77.3 | 40.7 | 0.6 |
| Location | At Township | | | | |
| Parameter | S0x | NOx | PM10 | PM2.5 | CO |
| Unit | ug/m3 | ug/m3 | ug/m3 | ug/m3 | mg/m3 |
| Avg | 11.9 | 23.8 | 61.8 | 34.1 | 0.5 |
| Min | 8.5 | 19.7 | 48.1 | 21.7 | 0.4 |
| Max | 13.8 | 26.2 | 74.3 | 44.2 | 0.5 |
| Location | At Dalchi Village | | | | |
| Parameter | S0x | NOx | PM10 | PM2.5 | CO |
| Unit | ug/m3 | ug/m3 | ug/m3 | ug/m3 | mg/m3 |
| Avg | 11.9 | 23.7 | 56.2 | 29.5 | <0.5 |
| Min | 9.8 | 19.3 | 45.6 | 23.3 | <0.5 |

| | | | | | |
|---|---|---|---|---|---|
| **Max** | 12.9 | 26.8 | 62.7 | 36.6 | <0.5 |

| **Surface Water Analysis Report** | | | | | |
|---|---|---|---|---|---|
| **For the period of Oct'23-Mar'24** | | | | | |
| **Parameter** | **Location** | **Vill.-Selda** | **Vill.-Dalchi** | **Vill.-Katora** | **Vill.-Jirbhar** |
| **PH** | _ | 7.5 | 7.5 | 7.6 | 7.8 |
| **TDS** | mg/L | 526 | 682 | 691 | 432 |
| **TSS** | mg/L | 25.0 | 4 | 3 | 4 |
| **BOD** | mg/L | 2.0 | 2 | 1 | 2 |
| **COD** | mg/L | 20.0 | 24 | 4 | 4 |
| **O&G** | mg/L | <4 | <4 | <4 | <4 |
| **Chlorides** | mg/L | 89.1 | 103.9 | 99.0 | 59.4 |
| **Sulphates** | mg/L | 21.3 | 42.4 | 41.3 | 22.4 |
| **Ca** | mg/L | 84.2 | 116.2 | 108.2 | 64.1 |
| **Mg** | mg/L | 48.6 | 70.5 | 60.8 | 38.9 |
| **Cd** | mg/L | <0.001 | <0.001 | <0.001 | <0.001 |
| **As** | mg/L | <0.005 | <0.005 | <0.005 | <0.005 |
| **Hg** | mg/L | <0.005 | <0.005 | <0.005 | <0.005 |
| **Pb** | mg/L | <0.005 | <0.005 | <0.005 | <0.005 |

| **Ground Water Analysis Report** | | | | | |
|---|---|---|---|---|---|
| **For the period of Oct'23-Mar'24** | | | | | |
| **Parameter** | **Location** | **Vill.-Dalchi (Nr. Ash Dyke)** | **Vill.-Selda** | **Vill.-Khedi** | **Vill.-Aarsi** |
| **PH** | _ | 7.8 | 7.8 | 7.7 | 7.7 |
| **TDS** | mg/L | 332 | 495 | 661 | 401 |
| **COD** | mg/L | <4 | <4 | <4 | <4 |
| **Chlorides** | mg/L | 39.6 | 99.0 | 123.7 | 79.2 |
| **Sulphates** | mg/L | 81.2 | 112.6 | 94.2 | 43.3 |
| **Ca** | mg/L | 40.1 | 68.1 | 112.2 | 52.1 |
| **Mg** | mg/L | 24.3 | 41.3 | 68.0 | 31.6 |
| **Cd** | mg/L | <0.001 | <0.001 | <0.001 | <0.001 |
| **As** | mg/L | <0.005 | <0.005 | <0.005 | <0.005 |
| **Hg** | mg/L | <0.005 | <0.005 | <0.005 | <0.005 |
| **Pb** | mg/L | <0.005 | <0.005 | <0.005 | <0.005 |

| **Ash Effluent Water Analysis Report** | | | | | |
|---|---|---|---|---|---|
| **For the period of Oct'23-Mar'24** | | | | | |
| **Parameter** | **Unit** | **Avg** | **Min** | **Max** | |
| **PH** | | 7.6 | 7.4 | 7.7 | |
| **TDS** | mg/L | 705 | 668 | 742 | |
| **TSS** | mg/L | 12.3 | 8.0 | 17.0 | |
| **As** | mg/L | <0.005 | <0.005 | <0.005 | |
| **Hg** | mg/L | <0.001 | <0.001 | <0.001 | |
| **Cr** | mg/L | <0.01 | <0.01 | <0.01 | |
| **Pb** | mg/L | <0.005 | <0.005 | <0.005 | |
| **Cd** | mg/L | <0.01 | <0.01 | <0.01 | |

| **Bottom Ash Analysis Report-Heavy Metals** | | |
|---|---|---|
| **For the period of Oct'23-Mar'24** | | |
| **Parameter** | **Unit** | **Result** |
| **Pb** | mg/L | <0.1 |
| **Cr-T** | mg/L | 0.18 |

| | | |
|---|---|---|
| **Cu** | mg/L | <0.1 |
| **Zn** | mg/L | <0.1 |
| **Ni** | mg/L | <0.1 |
| **As** | mg/L | <0.005 |
| **Hg** | mg/L | <0.1 |
| **Cd** | mg/L | <0.01 |
| **Mg** | mg/L | <0.1 |
| **Co** | mg/L | <0.1 |

## Coal Analysis Report-Heavy Metals

**For the period of Oct'23-Mar'24**

| Parameter | Unit | Result |
|---|---|---|
| **Pb** | mg/kg | 8.3 |
| **Cr-T** | mg/kg | 25.5 |
| **Cu** | mg/kg | 15.3 |
| **Zn** | mg/kg | 19.0 |
| **Ni** | mg/kg | 11.2 |
| **As** | mg/kg | 1.5 |
| **Hg** | mg/kg | 0.2 |
| **Co** | mg/kg | 0.4 |

**Final Report – 1st year**

# Review of Hydrogeology to Assess Impact of NTPC Khargone on Surface and Ground Regime (Especially around Ash Dyke) and Propose Specific Mitigation Measures

(After completion and incorporation of Pre and Post-monsoon analysis for 2023)

Submitted to

**NTPC Khargone Super Thermal Power Station**

Village: Selda & Dalchi, Tehsil: Badwah, District: Khargone, Madhya Pradesh

Submitted by

Prof. Manoj Kumar Jain (PI)

Prof. Brijesh Kumar Yadav (Co-PI)

DEPARTMENT OF HYDROLOGY

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

ROORKEE (UTTARAKHAND), INDIA

MARCH 2024

| | |
|---|---|
| Title | Review of Hydrogeology to Assess Impact of NTPC Khargone on Surface water and Ground Regime (Especially around Ash Dyke) and Propose Specific Mitigation Measures.<br><br>A study conducted by Department of Hydrology, Indian Institute of Technology Roorkee, Roorkee – 247667 (Uttarakhand) |
| Client | NTPC Limited |
| Disclaimer | While every opportunity has been taken to ensure the accuracy of the material presented in this document, IIT-Roorkee cannot be held responsible for errors or omissions but reserve the right to provide further clarification or consultation. The opinion contained in this report is our personal, professional opinion and should not be considered as the opinion of IIT Roorkee. |
| Document No. | HYD-6009/22-23/FR1 |
| NTPC PO No. | 4000294217-037-1019 |
| Consultants | Prof. Manoj Kumar Jain, Department of Hydrology<br>Prof. Brijesh K. Yadav, Department of Hydrology<br>Indian Institute of Technology, Roorkee, Uttarakhand 247667, India |
| Quality Assurance | Prof. Manoj Kumar Jain, Department of Hydrology<br><br>Prof. Brijesh K. Yadav, Department of Hydrology<br>Department of Hydrology, Indian Institute of Technology Roorkee, Roorkee – 247667, Uttarakhand, India |
| Date | 19 March 2024 |

# EXECUTIVE SUMMARY

A survey team comprised of Dr. Manoj Kumar Jain (Professor), Dr. Brijesh Kumar Yadav (Professor), Mr. Abhishek Kumar (Research Fellow), and Dr. Apoorv Verma (Scientific Administrative Assistant) from the Department of Hydrology, IIT Roorkee visited the NTPC Khargone, and its nearby areas along with the required instruments during April 25 – 30, 2023 and October 9 – 13, 2023 to undertake a survey of the power station area, ash dyke and other surrounding areas of the power station. The team identified relevant observation points in all directions for sample collection of surface and groundwater resources. Water samples were collected from the identified existing open wells, handpumps, tube wells, piezometers, ponds, reservoirs, rivers within a 10 km radius and ash dyke, NTPC station area, surface water reservoirs etc. The depth of the groundwater table was also measured using the existing open wells and piezometers available in and around the power station boundary. Some water quality parameters were measured in-situ during the field visit, and the remaining were analysed in the laboratories of the Department of Hydrology and Institute instrumentation centre (IIC) of IIT Roorkee. A summary of the field survey and a detailed analysis of collected data for the pre-and post-monsoon 2023 seasons are presented in this final report for the first year.

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# 1 INTRODUCTION AND OBJECTIVES OF THE STUDY

NTPC Limited is operating Khargone Super Thermal Power Station (KhSTPS) of capacity 1320 MW (2x660 MW), near villages Selda and Dalchi in Sanawad tehsil of Khargone district of Madhya Pradesh to meet the power demand of Western Region states like MP, Gujrat, Chhattisgarh, Maharashtra, Goa and daman & Diu. It is a coal based thermal power station based on environment friendly Ultra Supercritical Technology.

The coal requirement of 6.6 MTPA for the power station is brought from the CIL Subsidiaries, SECL, NCL & NTPC Captive mines through a railway line.

The makeup water requirement for the power station is about 3700 cum/hr with an ash water recirculation system. The water requirement is to be met from Omkareshwar dam, located at a distance of about 45 km from the power station. The Govt. of Madhya Pradesh has accorded a commitment for 40 MCM of water from the Narmada River for the project.

The major objective of this power project is power supply improvement in Madhya Pradesh State. 50% of the power generated from the station has been allocated to Madhya Pradesh State, 16.5% to Maharastra, 13.3% to Gujarat, 4% to Chhattisgarh, 0.7 % to Goa, DD & DNH. 15% of power kept as unallocated at the disposal of the Government of India (GoI) to meet short term emergencies, deficits of beneficiary states and allocation to other willing states of Western Region. This is subject to the approval of GoI.

The Khargone Super Thermal Power Station (KhSTPS) is located at a distance of about 105 Kms from Indore, about 30 Kms from Sanawad town, about 42 km from Barwah and at a distance of about 15 km from Bedia (on Sanawad-Khargone Road).

Khargone city is about 40 km from the project site. The KhSTPS is approachable from Sanawad on Indore – Khandwa State Highway through the PWD road. The nearest Railway Station is Sanawad on Indore – Khandwa which is about 32 Km. Khandwa is on the main line of the Central Railway on the Mumbai-Itarsi section. The Airport at Indore is located about 105 km from the study site.

Narmada River is passing at about 15 Km (North) from the project site. The KhSTPS is located geographically at (Lat 22°04'06.6" N; Long 75°51'18.4" E) on Survey of India (SoI) toposheet No. 46N/16.

The specific condition no. (xiii) under Environmental Clearance (EC) accorded by The Ministry of Environment, Forest and Climate Change (MoEF&CC) vide letter Ref. No. J-13012/54/2010-IA.II(T), dtd. 31/03/2015 stipulates, "Hydrogeology of the area shall be reviewed annually through an institute/organisation of repute to assess the impact of surface water and groundwater (especially around ash dyke). In case, any deterioration is observed, specific mitigation measures shall be undertaken immediately. Reports/data of water quality shall be submitted to the Regional Office of the Ministry every six months."In view of the above, NTPC issued an NIT No. NTPC/USSC-CPG2/9900248178 dated 15.10.2022 for Review of hydrogeology to assessment to assess impact of NTPC-Khargone on surface water and ground regime (especially around ash dyke). The Department of Hydrology, Indian Institute of Technology Roorkee, Roorkee participated in the tender process and the consultancy was successfully awarded to IITR by NTPC Khargone vide PO No. 4000294217-037-1019.

## *1.1 **Objectives***

The objectives of the study shall be as follows:

a. To assess and review the impact of Khargone STPS (2x660 MW) on soil, surface water and groundwater regime (especially around the ash dyke).
b. To suggest mitigation measures for remediation of surface water and groundwater regime, if any.

## *1.2 **Extent & Scope of the Study***

The geographical extent of the study area shall consist of an area within 10 km from the periphery of the project components (Main plant, Ash Pond area & Township). In addition, the source of water and, location of the intake point, type of intake structures (barrage, dam, intake well, intake channel etc.) shall also be covered in the study,

even if located beyond 10 km and significant for identification of the impact due to NTPC Khargone. Further, any significant surface or ground water body located within 10-15 Km which is likely to influence the project/get influenced from the project shall also be covered.

The scope of the project will be as follows.

### 1.2.1 Literature Review

The consultant has to undertake a detailed literature search for the documents/ reports already available for the study area with various agencies such as the Geological Survey of India, the State Department of Geology and Mining, Central and State Water Boards, State Water Resources/Irrigation departments, Central Water Commission, India Meteorological Department etc. Based on the review of the literature available, the consultant shall make a detailed plan for the study covering all the objectives.

### 1.2.2 Field Studies

#### 1.2.2.1 Hydro-geological investigations

i. Preparation of groundwater flow direction map in Pre-monsoon and Post-monsoon periods.

ii. Analysis of soil chemical properties, like EC, pH, major ions (Na, K, Ca, Mg, Fe, $CO_3$, $HCO_3$, Cl, $SO_4$, $NO_3$, $F^-$, and $PO_4$), and Heavy metals (Cd, Zn, Hg, As, Cr, Pb etc.) at 10 selected locations at surface, 30 cm and 60 cm depth.

#### 1.2.2.2 Surface water quality monitoring around the Ash-pond

i. Water quality parameters like pH, EC, DO, BOD, COD, major cations (Na, K, Ca, Mg, and Fe etc.), major anions ($CO_3$, $HCO_3$, Cl, $SO_4$, $NO_3$, $F^-$, and $PO_4$ etc.) and Heavy metals (Cd, Zn, Hg, As, Cr, Pb etc.) during Pre and Post monsoon seasons at 16 locations (including water bodies i.e. streams and ponds especially near ash pond, water bodies within 10 km, samples from ash ponds and raw water reservoir).

#### 1.2.2.3 **Groundwater monitoring network around the Ash-pond**

(To check leachability from ash pond):

i. Design of the groundwater level and quality observation network.

ii. Regular monitoring of groundwater level shall be carried out in network of existing wells and piezometers in the vicinity of the ash pond for Pre-monsoon and Post-monsoon. Water table monitoring and depletion status in and around the project area.

iii. Water quality parameters like, pH, EC, TDS, DO, Major cations (Na, K, Ca, Mg, and Fe etc.), major anions ($CO_3$, $HCO_3$, Cl, $SO_4$, $NO_3$, $F^-$, and $PO_4$.), heavy metals (Cd, Zn, Hg, As, Cr, Pb etc.) and isotope monitoring during Pre & Post monsoon seasons at 16 locations (including 6 piezometers and 10 existing hand pumps and/or bore wells).

# 2 DESCRIPTION OF THE STUDY AREA

## *2.1 General*

Khargone Super Thermal Power Station (KhSTPS) is a coal-based thermal power project located at villages Selda and Dalchi in Khargone district of Madhya Pradesh. It is the country's first ultra-super critical thermal power project generating 1.32GW power using 2X660MW ultra-supercritical coal-fired units. It is the first ultra-supercritical coal-fired unit in the country built on engineering, procurement, and construction (EPC) basis. The project received environmental clearance in March 2015, while site preparation works were started in July 2015. NTPC commissioned the first 660MW unit of the Khargone power station in August 2019, and the second unit of similar capacity was commissioned in April 2020.

The total quantum of land acquired for the power station, ash dyke and township is 428.899 Hectares (1059.498 Acres), comprising of 317.19 Hectares (783.7904 Acres) of private land and 111.709 Hectares (276.039 Acres) Govt. land and is in NTPC possession. In addition, land of about 115 Hectares (about 284 acres) has been acquired for the makeup water pipeline corridor.

While developing the details of water system for the project, utmost care has been taken to minimise water requirement as well as effluent generation. The main features of the water system shall include: (i) Re-circulating type C.W. system with cooling towers / Open System complying with MOEF requirements. (ii) In case of Cooling Towers, utilisation of Cooling Tower blow down for Coal dust suppression and extraction system, Service water system, Ash handling and Firefighting. (iii) Recycle and reuse of effluents from coal dust suppression and extraction system and service water system. (iv) Ash water recirculation system, and (v) Recirculation of filter backwash to clarifier inlet. An effluent management scheme consisting of collection, treatment, recirculation, and disposal of effluents has been implemented in order to optimise the makeup water requirement as well as liquid effluent generation.

## 2.2 *Location and Extent of Study Area*

The study area for this study consists of an area within 10 km of distance from the periphery of the power station, ash pond, and township. In addition, the source of water and, location of the intake point, type of intake structures (barrage, dam, intake well, intake channel etc.) shall also be covered for the study, even if located beyond 10 km and significant for identification of the impact due to NTPC Khargone. Further, any significant surface or groundwater body located within 10-15 km which is likely to influence the project/get influenced from the project shall also be covered. The index map showing the location of the NTPC Khargone power station is depicted in Figure 1Figure 1. Index map showing location of NTPC Khargone STPP.. An image showing the NTPC Khargone power station is shown in Figure 2, and the 10 km radius from the NTPC power station marked on a topographic map is shown in Figure 3.

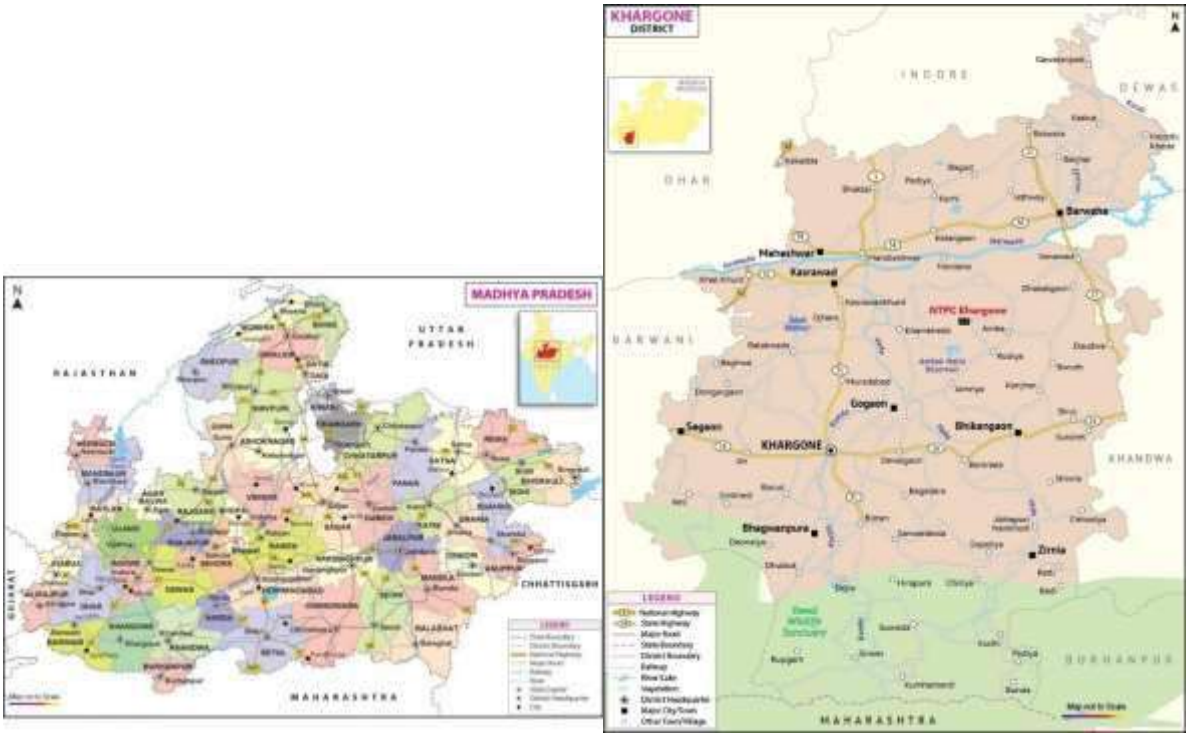


*Figure 1. Index map showing location of NTPC Khargone STPP.*


*Figure 2. Image showing NTPC Khargone Super Thermal Power Station*

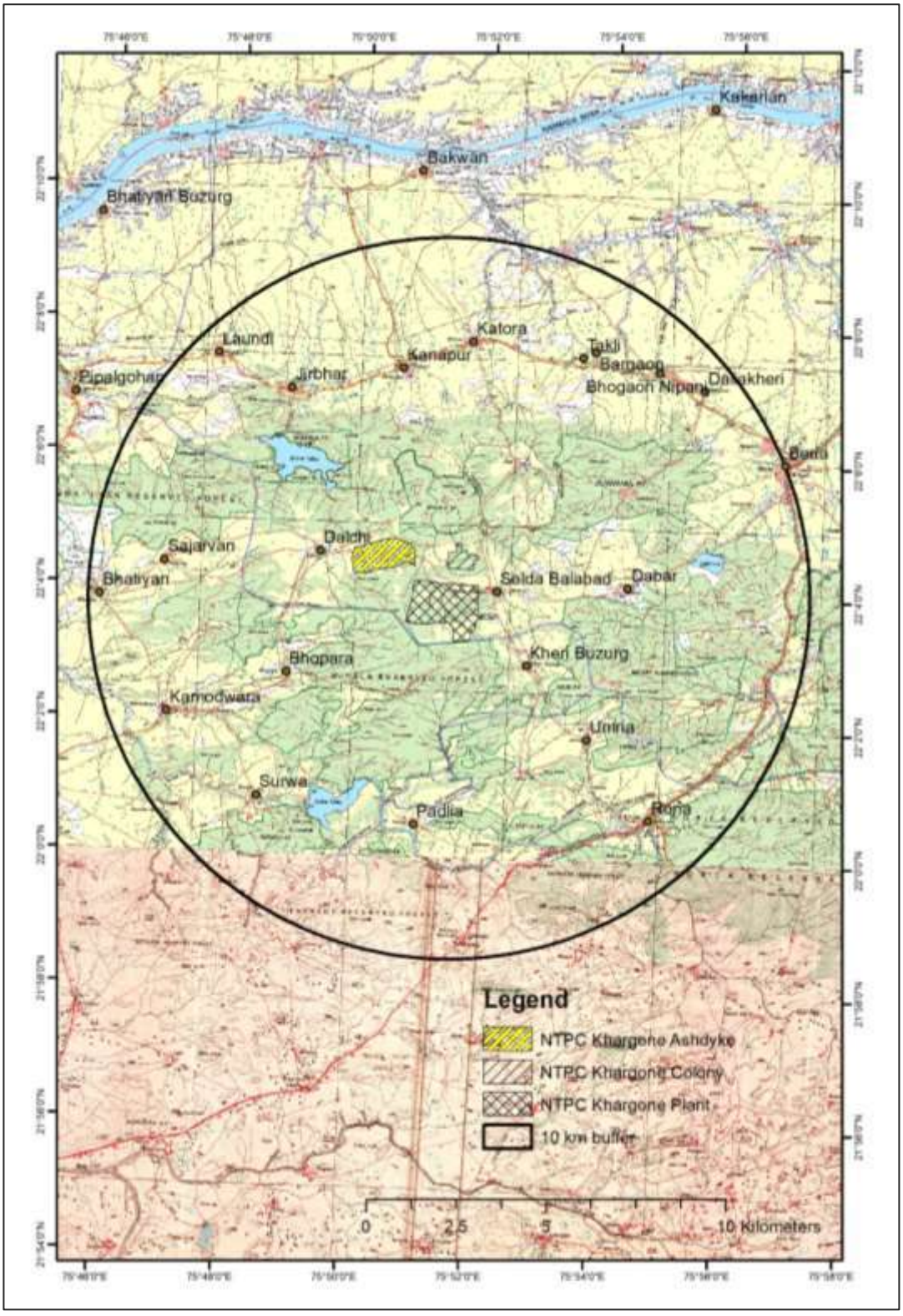


*Figure 3. The boundary of NTPC Khargone Super Thermal Power Station along with a 10 km buffer marked on Survey of India toposheets.*

## 2.3 *Topography of the Study Area*

The general topography of the study area was studied using the Survey of India toposheets 46O/13 & 46N/16, shown in Figure 3 and 1 arc second SRTM Digital Elevation Model (DEM) obtained from the Earth Explorer Website (https://earthexplorer.usgs.gov/). The DEM was processed in ArcGIS 10.8. The DEM of the study area is shown in Figure 4. The topography of the area is fairly undulating. The maximum and minimum elevation ranges between 240 and 260 m above mean sea level (amsl). The project area is a part of North Khargone tehsil, District Khargone, MP, which lies on the Deccan Plateau and has an average altitude of 250 m. The general slope of the area is towards the northwest. The general gradient of the area is towards NNW. The slope map of the study area is shown in Figure 5, which clearly shows the undulating topography of the area.

## 2.4 *Drainage of the Study Area*

The drainage map of the study area has been prepared using SRTM DEM, shown in Figure 4. The DEM was processed in ArcGIS 10.8 to generate the drainage map of the study area. The generated drainage map of the area is shown in Figure 6. In general, the drainage pattern of the study area is dendritic in nature. The Narmada River flows about 11.5 km in the North direction from the power station area. The Vamsali and Ambak Rivers, both tributaries of the Narmada River, mainly drain the area. The flow pattern in the 10 km circle of the study area is seen to have two distinct patterns. One flows towards the eastern side and the other towards the western side. The NTPC power station is located in the watershed draining towards the eastern watershed, while the ash dyke is located in the watershed draining towards the western side. Few water bodies could also be seen in the study area, mostly used for agricultural purposes by local farmers.

## 2.5 *Soil and Vegetation*

Generally, there are five types of soils, namely Kali I, (0-1 metre below ground level (mbgl)) and Kali II (1-2 mbgl) (2-3 mbgl) Halkikhardri and Bardi. These soils are

classified as medium black cotton soils containing 50% silt and clay together. Alluvial soil is found on both sides of the river Narmada and has some patches along its tributaries.

The study area has sparse vegetation, mainly open scrub type. The land area around the NTPC Khargone project does not have dense vegetation cover. Various kinds of trees, herbs, shrubs, climbers and grasses surround the area near the project.

## *2.6 **Land use / Land Cover***

The Main Land use pattern of the district comprises agricultural land, Forest, Fallow and settlement. Most part of the surrounding area of the project is covered by agricultural land, supporting single to multi crop pattern.

Broadly, the various land uses have been grouped under five categories, namely, Agricultural land (51.6%), Forest (27.7%), Settlement (2.3%), Waterbodies (3.6%), barren land (4.8%) and

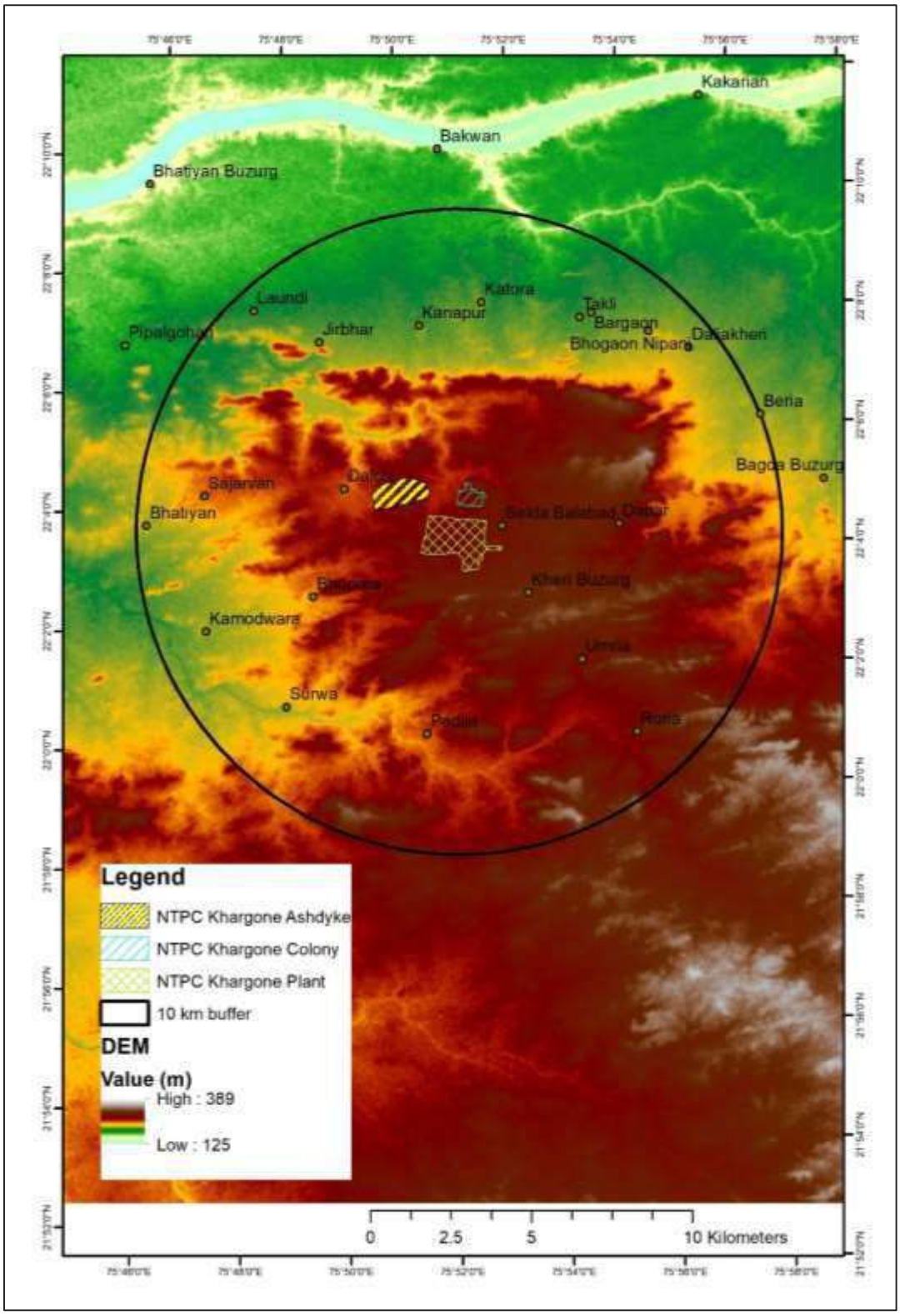


*Figure 4. DEM of the Study Area*

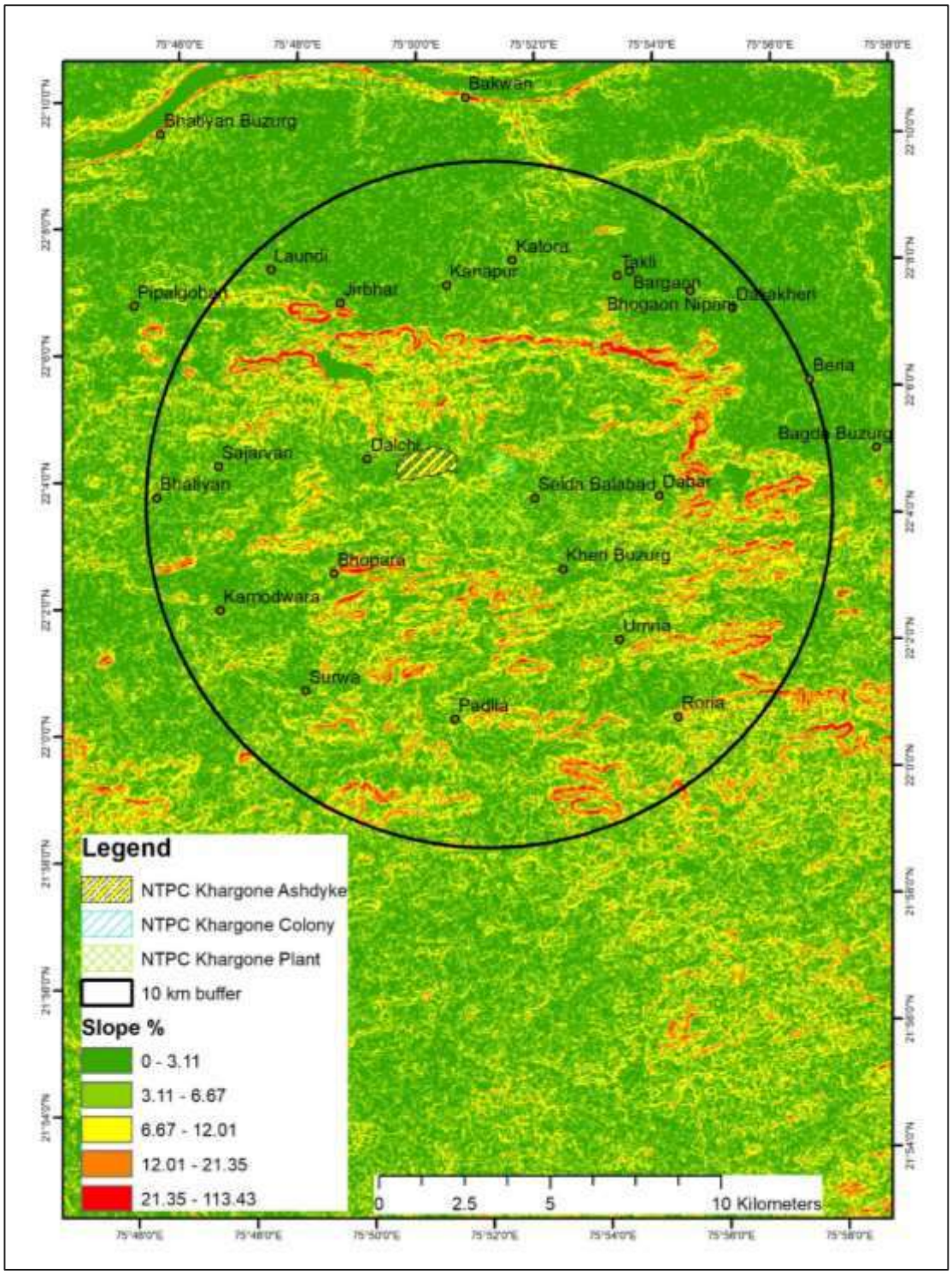


*Figure 5. Slope map of the study area.*

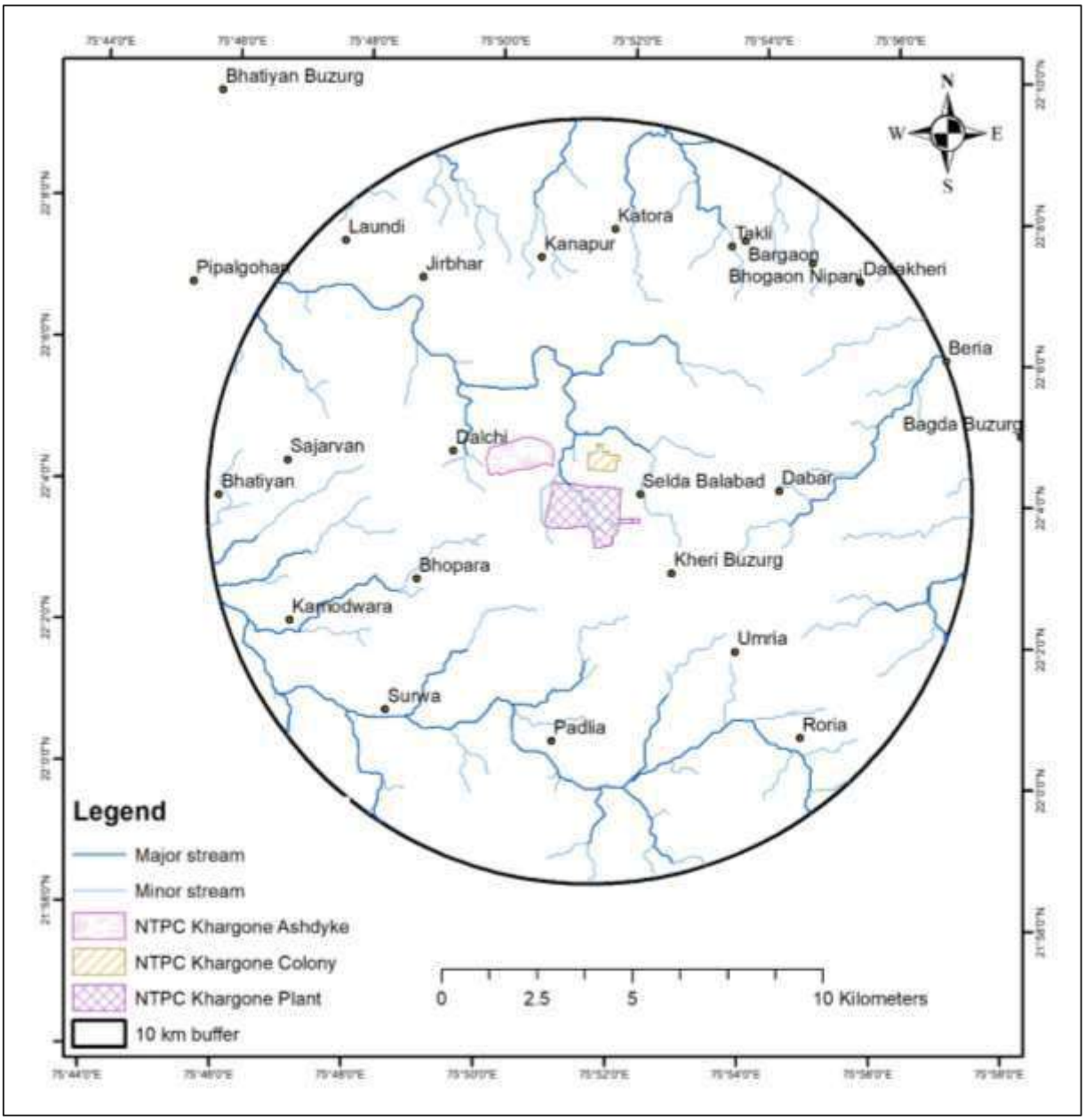


*Figure 6. Drainage map of the study area.*

# 3 RECONNAISANCE SURVEY

A field visit to the NTPC Khargone was undertaken by Professor of IIT Roorkee during February 2023. A reconnaissance survey of the study area was undertaken during this visit. A meeting was also held with officials of NTPC to discuss the fieldwork, proposed methodology and upcoming pre-monsoon visit. Some photographs of the reconnaissance field visit are shown in Figure 7.

*Figure 7. Some field photographs of reconnaissance survey during February 2023*

# 4 FIELD INVESTIGATIONS

## *4.1 Pre-monsoon 2023 field investigations*

A site visit was undertaken for pre-monsoon sampling and field investigations by the IIT Roorkee team during April 25 – 30, 2023. During this field visit, the following field works were undertaken.

i. Surface water sampling from 12 locations of surface water, including samples from various sources such as river water, lagoons, raw water reservoirs and ponds/lakes for studying surface water quality.
ii. Ground water sampling from 18 locations, including samples from various sources such as hand pumps, tube wells, open wells, and seepage nalah.
iii. Ground water levels monitoring at 16 locations, including hand pumps, tube wells, and open wells.
iv. Collection of soil samples from 11 locations.
v. In-situ determination of latitude, longitude, and elevation (altitude) for the various sampling locations.
vi. Site photograph during sampling. The site photographs are provided in Appendix-I.

## *4.2 Post-monsoon 2023 field investigations*

A site visit was undertaken for post-monsoon 2023 sampling and field investigations by the IIT Roorkee team during October 9 – 13, 2023. During this field visit, the following field works were undertaken.

vii. Surface water sampling from 12 locations of surface water, including samples from various sources such as river water, lagoons, raw water reservoirs and ponds/lakes for studying surface water quality.
viii. Ground water sampling from 18 locations, including samples from various sources such as hand pumps, tube wells, open wells, and seepage nalah.
ix. Ground water levels monitoring at 16 locations, including hand pumps, tube wells, and open wells.

x. Collection of soil samples from 11 locations.

xi. In-situ determination of latitude, longitude, and elevation (altitude) for the various sampling locations.

xii. Site photograph during sampling. The site photographs are provided in the Appendix-I.

# 5 GROUNDWATER LEVEL AND FLOW DIRECTION

The groundwater level is a key parameter for evaluating spatial and temporal changes in groundwater environments. The groundwater level is governed by various factors. Any phenomenon that produces pressure change within an aquifer result in the change of ground water level. These changes in ground water level can be a result of changes in storage, amount of discharge and recharge, variation of stream stages and evaporation. For defining the present hydro-geological scenario of the study area, the groundwater table is measured directly at various locations available within the study area for preparing the water table contour and flow direction maps.

## *5.1 Ground water level observations during Pre-Monsoon 2023 season*

In the present study, groundwater level monitoring for the pre-monsoon season of 2023 was carried out during April 25 – 30, 2023, at 20 locations in existing open/tube wells and piezometers. Figure 9 provides the location map of the groundwater level monitoring stations used for measuring water levels during the pre-monsoon 2023 visit. The details of the monitoring stations are provided in Table 1.

*Table 1. Details of ground water level monitoring stations during pre-monsoon of 2023.*

| S.No. | Site Code | Latitude (˚E) | Longitude (˚N) | Location and source | Ground Elevation (m amsl) |
|---|---|---|---|---|---|
| 1 | KHR-5 | 22.12494 | 75.8952 | Inside Primary School, Vill Badgaon, Handpump | 192 |
| 2 | KHR-5A | 22.12407 | 75.89518 | Adjacent to main road, Vill Badgaon, open well | 190 |
| 3 | KHR-7A | 22.12314 | 75.7963 | Londhi village, open well | 189 |
| 4 | KHR-7B | 22.12126 | 75.79317 | Londhi village, open well | 192 |
| 5 | KHR-13 | 22.06608 | 75.87139 | Adjoining of NTPC Community Centre Near New Hanumaan Temple, open well | 263 |
| 6 | KHR-15A | 22.07092 | 75.85599 | Near Bhilal Baba Temple, opp cooling tower, Near NTPC Gate no. 1, below mango tree, open well | 247 |
| 7 | KHR-16A | 22.07912 | 75.80412 | Adjacent to Gangour thermal power station road | 238 |
| 8 | KHR-18 | 22.06295 | 75.85256 | Well inside power station, open well | 249 |
| 9 | KHR-20A | 22.0833 | 75.8515 | Maal Singh Jhapdiya Well, Jamniya village, open well | 231 |
| 10 | KHR-21 (N1) | 22.12321 | 75.90812 | Adjacent to pipalgone road, open well | 198 |
| 11 | KHR-22 (N2) | 22.11305 | 75.92877 | Adjacent to pipalgone road, open well | 206 |
| 12 | KHR-23 (N3) | 22.10902 | 75.93549 | Adjacent to pipalgone road, open well | 198 |
| 13 | KHR-24 (N4) | 22.04485 | 75.87855 | Adjacent to Umaria road, open well | 273 |
| 14 | KHR-26 (N6) | 21.99242 | 75.86363 | in the field adjacent to Padaliya road, open well | 228 |
| 15 | KHR-Pz1 | 22.07826 | 75.8367 | Peizometer 1, Ash Dyke | 241 |

| | | | | | |
|---|---|---|---|---|---|
| 16 | KHR-Pz2 | 22.07721 | 75.83306 | Peizometer 2, Ash Dyke | 239 |
| 17 | KHR-Pz3 | 22.07476 | 75.83177 | Peizometer 3, Ash Dyke | 234 |
| 18 | KHR-Pz4 | 22.07289 | 75.83233 | Peizometer 4, Ash Dyke | 230 |
| 19 | KHR-Pz5 | 22.07055 | 75.83277 | Peizometer 5, Ash Dyke | 236 |
| 20 | KHR-Pz6 | 22.07089 | 75.83548 | Peizometer 6, Ash Dyke | 238 |

The water level below the ground surface was measured using a dip-meter with a water level indicator. DGPS Survey was carried out in the earlier study by NIH at most of these locations, and based on the DGPS data, elevation of the location was determined. The elevation data was used to determine the water level elevation above the mean sea level (amsl). The water level data (both below the ground level and above mean sea level) is presented in Table 2. The spatial variation of water depth below the ground surface is also shown in Figure 8.

The measured depth to the groundwater table has been used as a base parameter to delineate the groundwater flow pattern in and around the NTPC power station. The groundwater contour map (Figure 9) was prepared by using measured water table depth data listed in Table 2 pre-monsoon 2023 season. Figure 9 was produced using the feature of ArcMap in which vector field rendering (arrow representation) was performed for better visualisation of flow direction. The thinning method uses a vector averaging procedure to calculate the direction and magnitude for each pixel to generate the flow map. Figure 9 suggests that the groundwater generally flows in two distinct patterns. The groundwater flow in the area to the north of the power station flows northwards towards Narmada River, and the groundwater in the area to the southern side of the power station flows towards south and southwest direction. A slight variation in the movement of groundwater around the power station site seems to be due to a dense network of measuring wells. Secondary porosities like weathering, fracturing, faulting, and other lineaments in the study area can also cause such flow variations. The groundwater table contour map of the area is found mostly in line with its surface drainage pattern.

*Table 2. Measured groundwater level at identified locations in the area during the pre-monsoon season (April 2023).*

| S.No. | Site Code | Latitude (˚E) | Longitude (˚N) | Location and source | Depth to water table (m) | Water Table Elevation (m amsl) |
|---|---|---|---|---|---|---|
| 1 | KHR-5 | 22.12494 | 75.8952 | Vill Badgaon, Handpump | 2.2 | 189.8 |
| 2 | KHR-5A | 22.12407 | 75.89518 | Adjacent to main road, Vill Badgaon, open well | 3.6 | 186.4 |
| 3 | KHR-7A | 22.12314 | 75.7963 | Londhi village, open well | 6.6 | 182.4 |
| 4 | KHR-7B | 22.12126 | 75.79317 | Londhi village, open well | 6.78 | 185.22 |
| 5 | KHR-13 | 22.06608 | 75.87139 | Adjoining of NTPC Community Centre Near New Hanumaan Temple, open well | 7.9 | 255.1 |
| 6 | KHR-15A | 22.07092 | 75.85599 | Near Bhilal Baba Temple, opp cooling tower, Near NTPC Gate no. 1, below mango tree, open well | 1.55 | 245.45 |
| 7 | KHR-16A | 22.07912 | 75.80412 | Adjacent to Gangour thermal power station road | 12.4 | 225.6 |
| 8 | KHR-18 | 22.06295 | 75.85256 | Well inside power station, open well | 4.56 | 244.44 |
| 9 | KHR-20A | 22.0833 | 75.8515 | Maal Singh Jhapdiya Well, Jamniya village, open well | 1.5 | 229.5 |
| 10 | KHR-21 (N1) | 22.12321 | 75.90812 | Adjacent to pipalgone road, open well | 5.2 | 192.8 |
| 11 | KHR-22 (N2) | 22.11305 | 75.92877 | Adjacent to pipalgone road, open well | 5.4 | 200.6 |
| 12 | KHR-23 (N3) | 22.10902 | 75.93549 | Adjacent to pipalgone road, open well | 2.3 | 195.7 |
| 13 | KHR-24 (N4) | 22.04485 | 75.87855 | Adjacent to Umaria road, open well | 9 | 264 |
| 14 | KHR-26 (N6) | 21.99242 | 75.86363 | in the field adjacent to Padaliya road, open well | 2.9 | 225.1 |
| 15 | KHR-Pz1 | 22.07826 | 75.8367 | Peizometer 1, Ash Dyke | 2.7 | 238.3 |
| 16 | KHR-Pz2 | 22.07721 | 75.83306 | Peizometer 2, Ash Dyke | 12.33 | 226.67 |
| 17 | KHR-Pz3 | 22.07476 | 75.83177 | Peizometer 3, Ash Dyke | 3.3 | 230.7 |
| 18 | KHR-Pz4 | 22.07289 | 75.83233 | Peizometer 4, Ash Dyke | 3.5 | 226.5 |
| 19 | KHR-Pz5 | 22.07055 | 75.83277 | Peizometer 5, Ash Dyke | 9.4 | 226.6 |
| 20 | KHR-Pz6 | 22.07089 | 75.83548 | Peizometer 6, Ash Dyke | 9.5 | 228.5 |

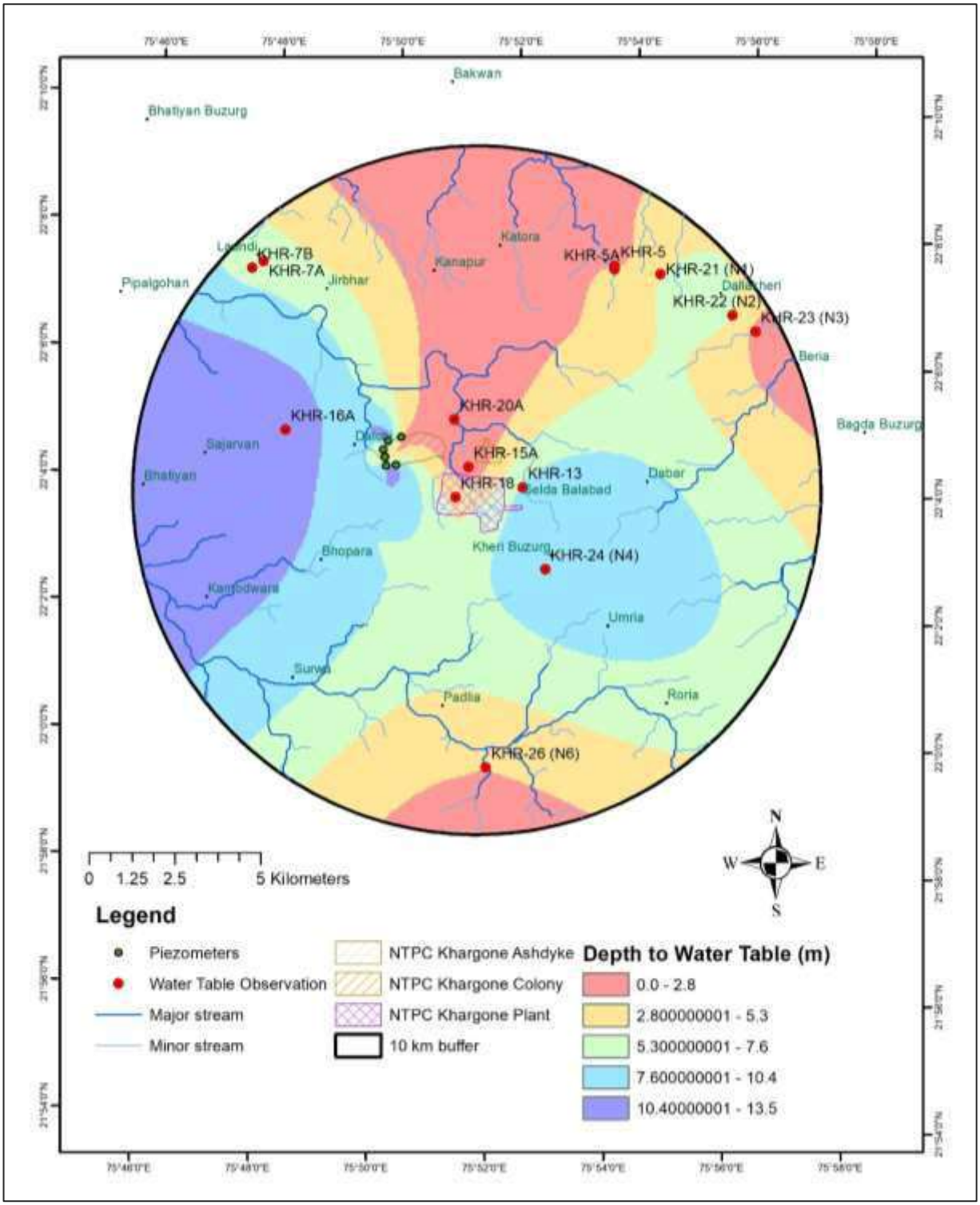


*Figure 8. Map showing spatial variation of water table depth below ground level for pre-monsoon 2023 season.*

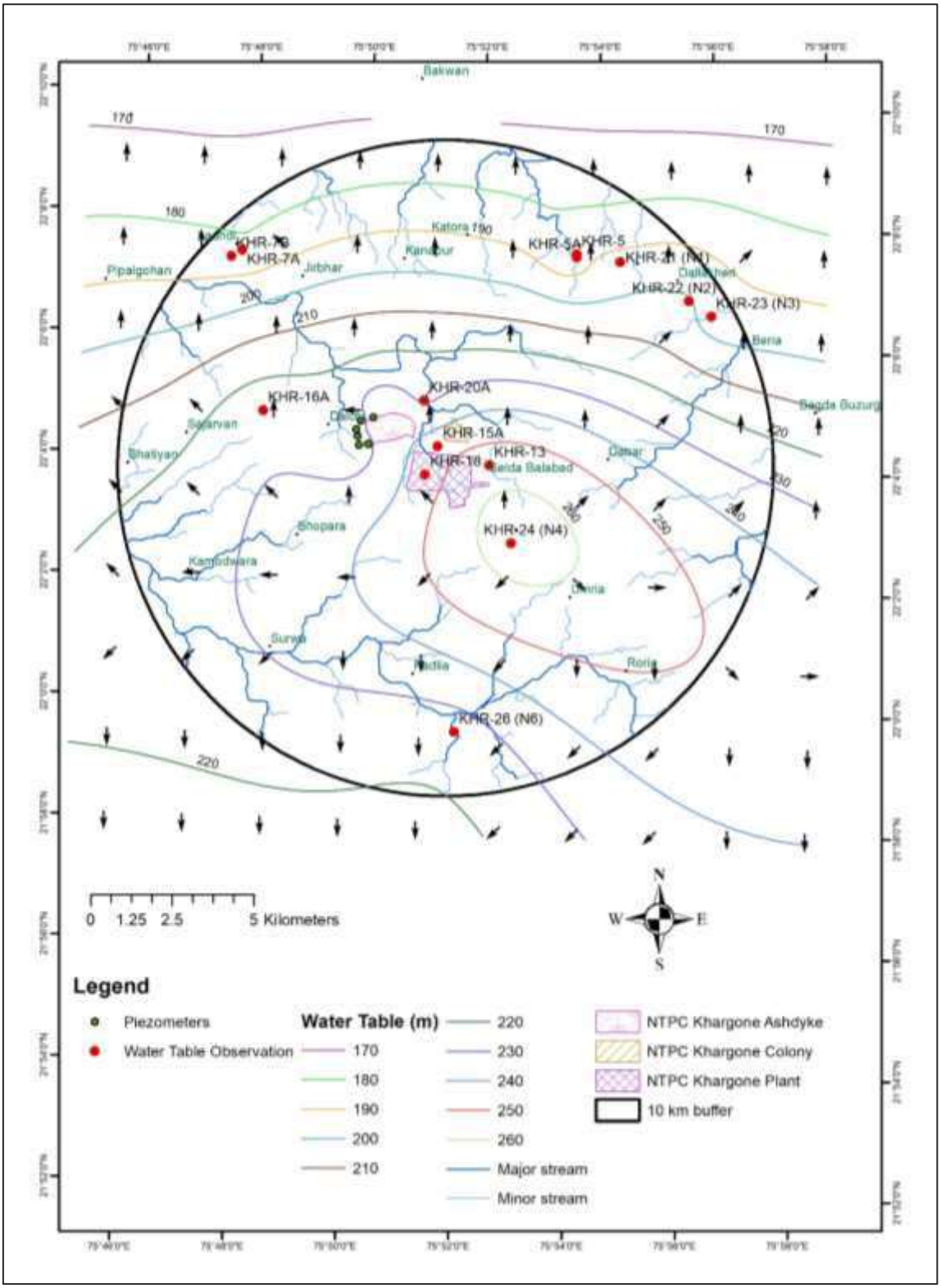


*Figure 9. Map depicting ground water table contours and flow direction in the study area during Pre-monsoon 2023.*

## 5.2 *Ground water level observations during post-monsoon 2023 season*

The groundwater level monitoring for the post-monsoon season of 2023 was carried out during October 9-13, 2023, at 29 locations using existing open/tube wells and piezometers. Two of the existing open wells (KHR-15 and KHR-61AE) were skipped during this post-monsoon season due to an unforeseen situation at the sampling time. Figure 9 provides the location map of the groundwater level monitoring stations used for measuring water level during the pre-monsoon 2023 visit. The details of the monitoring stations are provided in Table 1.

*Table 3. Details of ground water level monitoring stations during post monsoon season of 2023.*

| S.No. | Site Code | Latitude (˚E) | Longitude (˚N) | Location and source | Elevation |
|---|---|---|---|---|---|
| 1 | KHR-4 | 22.068803 | 75.862023 | Between NTPC & Town ship, opposite to Boundary Pillar S.N. 230-240 | 254 |
| 2 | KHR-5 | 22.12494 | 75.8952 | Vill Badgaon, Handpump | 192 |
| 3 | KHR-5A | 22.12407 | 75.89518 | Adjacent to main road, Vill Badgaon, open well | 190 |
| 4 | KHR-6A | 22.12545 | 75.84165 | Well in the field, Vill Kanapur | 188 |
| 5 | KHR-7A | 22.12314 | 75.7963 | Londhi village, open well | 189 |
| 6 | KHR-7B | 22.12126 | 75.79317 | Londhi village, open well | 192 |
| 7 | KHR-8A | 22.10271 | 75.75548 | Karan Gangle Handpump, Pipalgone village. | 185 |
| 8 | KHR-10A | 22.04086 | 75.81116 | Near Anganwadi Kendra, Bhopada | 219 |
| 9 | KHR-13 | 22.06608 | 75.87139 | Adjoining of NTPC Community Centre Near New Hanumaan Temple, open well | Discarded |
| 10 | KHR-15A | 22.07092 | 75.85599 | Near Bhilal Baba Temple, opp cooling tower, Near NTPC Gate no. 1, below mango tree, open well | 247 |
| 11 | KHR-16A | 22.07912 | 75.80412 | Adjacent to Gangour thermal power station road | Discarded |
| 12 | KHR-18 | 22.06295 | 75.85256 | Well inside power station, open well | 249 |
| 13 | KHR-20A | 22.0833 | 75.8515 | Maal Singh Jhapdiya Well, Jamniya village, open well | 231 |
| 14 | KHR-21 | 22.12321 | 75.90812 | Adjacent to pipalgone road, open well | 198 |
| 15 | KHR-22 | 22.11305 | 75.92877 | Adjacent to pipalgone road, open well | 206 |
| 16 | KHR-23 | 22.10902 | 75.93549 | Adjacent to pipalgone road, open well | 198 |
| 17 | KHR-24 | 22.04485 | 75.87855 | Adjacent to Umaria road, open well | 273 |

| | | | | | |
|---|---|---|---|---|---|
| 18 | KHR-25 | 22.02839 | 75.89527 | In front of Rewa Gurjar Dharamshala, Gram panchayat office, Umaria | 251 |
| 19 | KHR-26 | 21.99242 | 75.86363 | In the field adjacent to Padaliya road, open well | 228 |
| 20 | KHR-27 | 22.00855 | 75.90918 | Rodiya Bus Stop, Near Teashop | 245 |
| 21 | KHR-28 | 21.97891 | 75.86348 | Ahirkheda, Near Patrol pump | 244 |
| 22 | KHR-29 | 22.02219 | 75.87928 | Sala Village, Shivram well | 248 |
| 23 | KHR-30 | 22.04405 | 75.85148 | Umardad, Adjacent to road | 270 |
| 24 | KHR-31 | 22.065 | 75.88535 | Dabar | 269 |
| 25 | KHR-32 | 22.10956 | 75.96084 | Bediya | 192 |
| 26 | KHR-Pz1 | 22.07826 | 75.8367 | Peizometer 1, Ash Dyke | 241 |
| 27 | KHR-Pz2 | 22.07721 | 75.83306 | Peizometer 2, Ash Dyke | 239 |
| 28 | KHR-Pz3 | 22.07476 | 75.83177 | Peizometer 3, Ash Dyke | 234 |
| 29 | KHR-Pz4 | 22.07289 | 75.83233 | Peizometer 4, Ash Dyke | 230 |
| 30 | KHR-Pz5 | 22.07055 | 75.83277 | Peizometer 5, Ash Dyke | 236 |
| 31 | KHR-Pz6 | 22.07089 | 75.83548 | Peizometer 6, Ash Dyke | 238 |

The measured depth to the groundwater table has been used as a base parameter to delineate the groundwater flow pattern in and around the NTPC power station. The groundwater contour map (Figure 9) was produced using the feature of ArcMap in which vector field rendering (arrow representation) was performed for better visualisation of flow direction. Figure 9 suggests that the groundwater generally flows in two distinct patterns which is similar to the pre-monsoon period. The groundwater flow in the area to the north of the power station flows northwards towards Narmada River, and the groundwater in the southern side of the power station flows towards south and southwest direction. A slight variation in the movement of groundwater around the power station site seems to be due different water use/recharge through a dense network of measuring wells. In general, the groundwater table contour map of the area is found mostly in line with its surface drainage pattern. Table 4 shows the measured groundwater level at identified locations in the area during the post-monsoon season (October 2023). Figure 11 shows the map depicting ground water table contours and flow direction in the study area during the post-monsoon 2023.

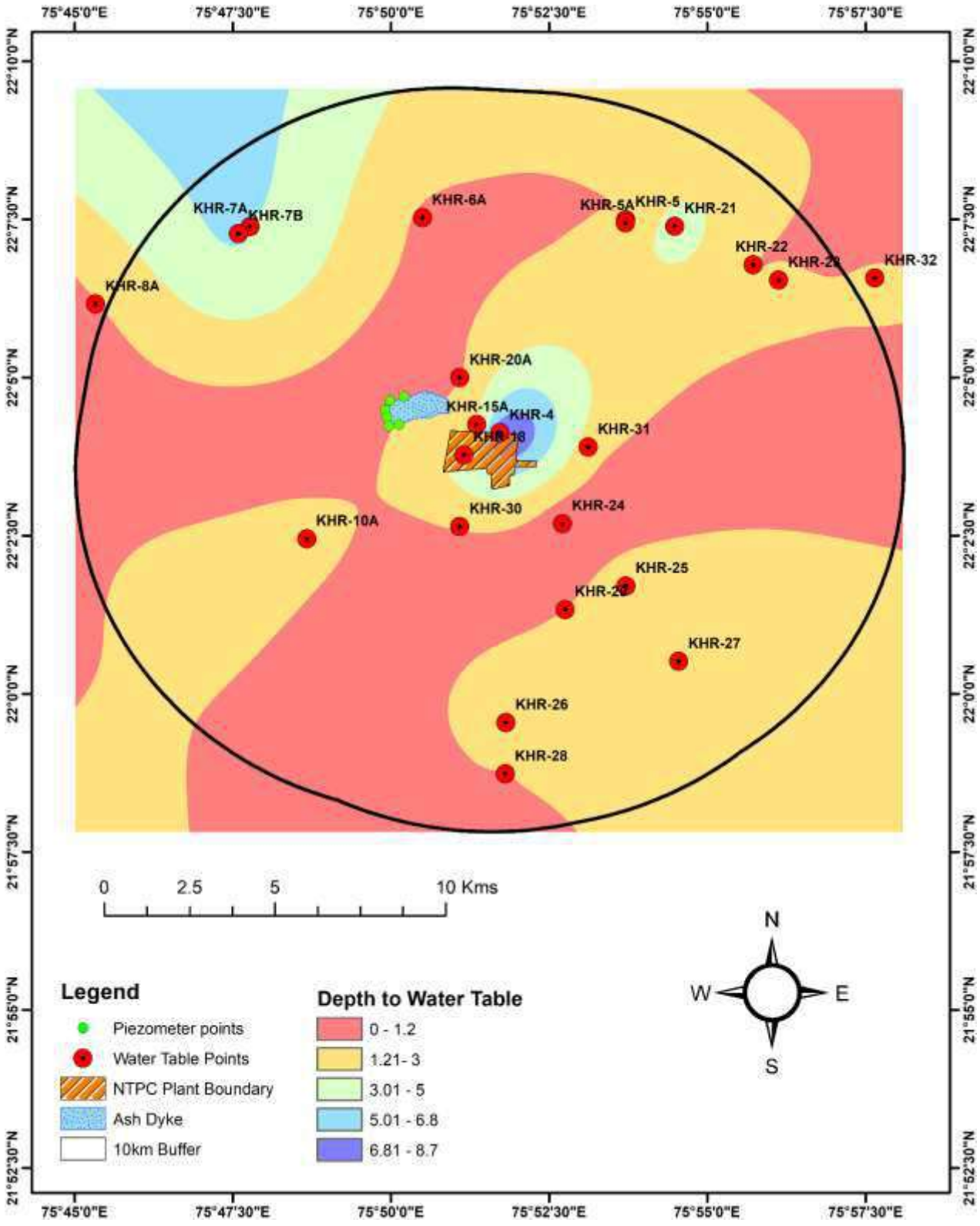


*Figure 10. Map showing spatial variation of water table depth below ground level for pre-monsoon 2023 season.*

*Table 4. Measured groundwater level at identified locations in the area during the post-monsoon season (October 2023).*

| S.No. | Site Code | Latitude (˚E) | Longitude (˚N) | Depth to water table (m) | Water Table Elevation (m amsl) |
|---|---|---|---|---|---|
| 1 | KHR-4 | 22.068803 | 75.862023 | 8.68 | 245.32 |
| 2 | KHR-5 | 22.12494 | 75.8952 | 1.1 | 190.9 |
| 3 | KHR-5A | 22.12407 | 75.89518 | 2.25 | 187.75 |
| 4 | KHR-6A | 22.12545 | 75.84165 | 1.02 | 186.98 |
| 5 | KHR-7A | 22.12314 | 75.7963 | 5 | 184 |
| 6 | KHR-7B | 22.12126 | 75.79317 | 5.2 | 186.8 |
| 7 | KHR-8A | 22.10271 | 75.75548 | 1.09 | 183.91 |
| 8 | KHR-10A | 22.04086 | 75.81116 | 1.8 | 217.2 |
| 9 | KHR-13 | 22.06608 | 75.87139 | | **Discarded** |
| 10 | KHR-15A | 22.07092 | 75.85599 | 1.78 | 245.22 |
| 11 | KHR-16A | 22.07912 | 75.80412 | | **Discarded** |
| 12 | KHR-18 | 22.06295 | 75.85256 | 4.1 | 244.9 |
| 13 | KHR-20A | 22.0833 | 75.8515 | 1.1 | 229.9 |
| 14 | KHR-21 | 22.12321 | 75.90812 | 3.38 | 194.62 |
| 15 | KHR-22 | 22.11305 | 75.92877 | 1.22 | 204.78 |
| 16 | KHR-23 | 22.10902 | 75.93549 | 1.42 | 196.58 |
| 17 | KHR-24 | 22.04485 | 75.87855 | 0.3 | 272.7 |
| 18 | KHR-25 | 22.02839 | 75.89527 | 2 | 249 |
| 19 | KHR-26 | 21.99242 | 75.86363 | 2.62 | 225.38 |
| 20 | KHR-27 | 22.00855 | 75.90918 | 2.6 | 242.4 |
| 21 | KHR-28 | 21.97891 | 75.86348 | 1.2 | 242.8 |
| 22 | KHR-29 | 22.02219 | 75.87928 | 1.2 | 246.8 |
| 23 | KHR-30 | 22.04405 | 75.85148 | 1.3 | 268.7 |
| 24 | KHR-31 | 22.065 | 75.88535 | 2 | 267 |
| 25 | KHR-32 | 22.10956 | 75.96084 | 1.3 | 190.7 |
| 26 | KHR-Pz1 | 22.07826 | 75.8367 | 2.1 | 238.9 |
| 27 | KHR-Pz2 | 22.07721 | 75.83306 | 9.27 | 229.73 |
| 28 | KHR-Pz3 | 22.07476 | 75.83177 | 2.42 | 231.58 |
| 29 | KHR-Pz4 | 22.07289 | 75.83233 | 1.2 | 228.8 |
| 30 | KHR-Pz5 | 22.07055 | 75.83277 | 7.1 | 228.9 |
| 31 | KHR-Pz6 | 22.07089 | 75.83548 | 5.5 | 232.5 |

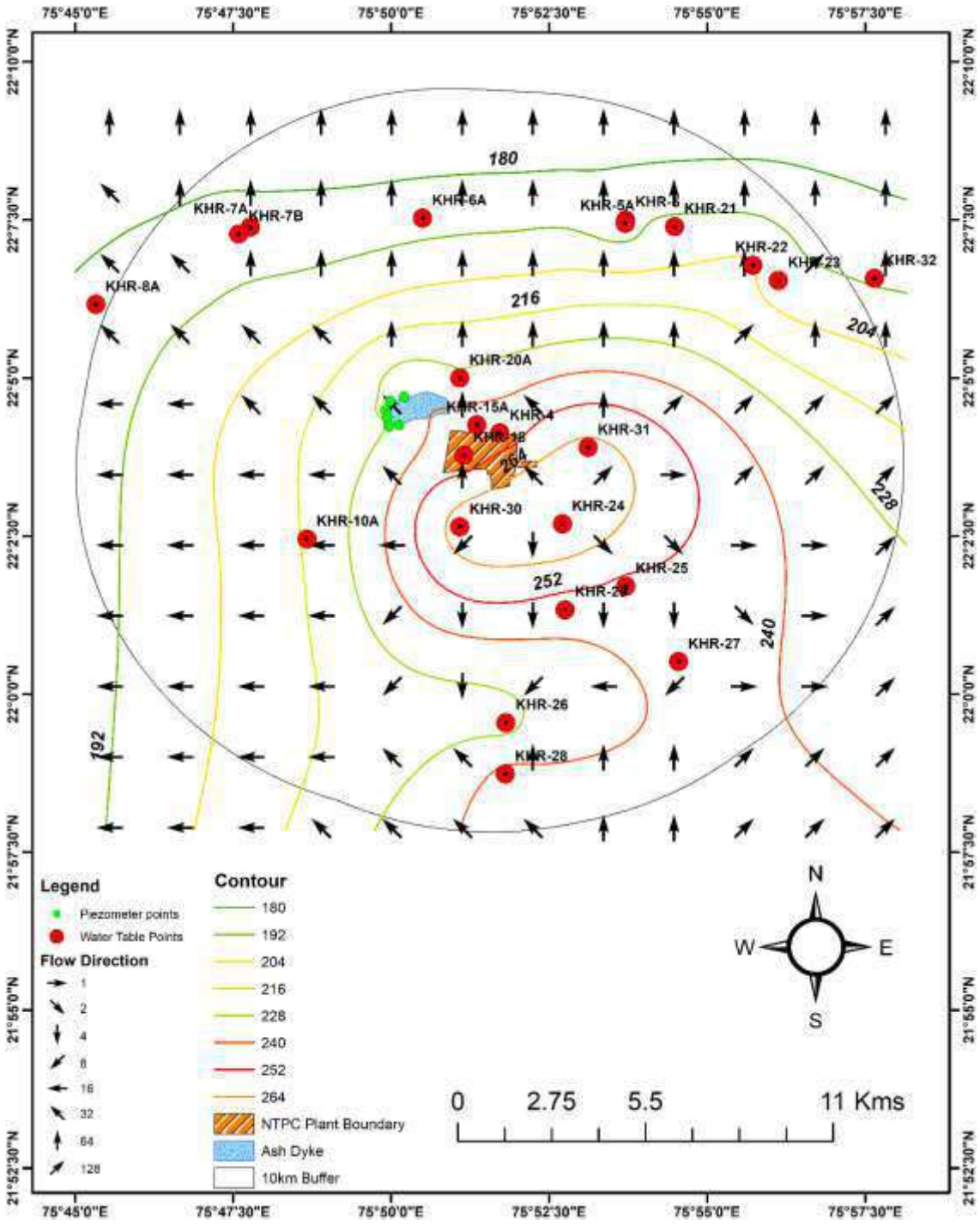


*Figure 11. Map depicting ground water table contours and flow direction in the study area during the Post-monsoon 2023.*

## *5.3 Analysis of Ground water level trend with previous reports*

The comparison of groundwater levels data between pre and post-monsoon periods is essential for hydrogeological studies. This comparative analysis provides valuable insights into the seasonal fluctuations and dynamics of groundwater resources. By examining the changes in water levels before and after the monsoon, we may determine trends and identify potential influences on aquifer recharge or depletion, and assess the overall health of groundwater systems. This assessment is particularly crucial for understanding the impact of seasonal variations on water availability and can help in adopting sustainable water resource management strategies. The analysis involves collecting groundwater level data during both pre-monsoon and post-monsoon seasons, calculating the differences or fluctuations between these periods, and interpreting the results to draw meaningful conclusions about groundwater storage and flow regimes.

The groundwater table data presented in the Table 5 pertains to various monitoring sites, each identified by a unique site code, latitude and longitude coordinates for the year 2023. The dataset encompasses measurements during both pre-monsoon (PreM) and post-monsoon (PostM) seasons, with associated fluctuation values denoting the difference between these seasons. Fluctuation in groundwater can be positive to negative, representing rise and decline in groundwater levels, respectively. KHR-5 demonstrates a rise in groundwater levels from PreM (2.2 m) to PostM (1.1 m). Similarly, KHR-7A and KHR-7B both experience a rise in groundwater levels post-monsoon, with fluctuations of 1.6 and 1.58 meters, respectively. On the other hand, KHR-15A observes a minor fall with a fluctuation of -0.23 m. These diverse trends underscore the complex and heterogeneous nature of groundwater dynamics of the study area.

Groundwater level fluctuation in the buffer zone and trend based secondary data were also collected by National Institute of Hydrology (NIH)- Roorkee in year 2018 during pre-and post-monsoon periods. Amba site experiences a substantial fluctuation of 16.8 m, signalling a noteworthy increase. Similarly, Dabhad, Dalchi, Bhatyan Khurd, Pipalgon, Londhi, Kanapur, Badgaon, Satkhali, Padliya Gawli, and others locations

showcase substantial fluctuations, all indicative of a rise in groundwater level during the post-monsoon season. Notably, Satkhali demonstrates the highest fluctuation of 24.7 m. This positive trend suggests an overall rise in the water table over the specified period. However, it is crucial to note a significant limitation in the interpretation of the findings. The data sets presented in Table 6 were collected from diverse sources, including tube wells, bore wells, and handpumps, by the NIH Roorkee in 2018. This heterogeneity in data collection methods and sources introduces a notable challenge in directly comparing the water level measurements for precise assessment. The variability in measurement techniques and instrument types used for tube wells, bore wells, and handpumps can lead to some other disparities in the reported data, making it difficult to establish a direct and meaningful comparison. Moreover, the data collected by NIH in year 2022 is available only for the pre -monsoon period. Therefore, a meaningful comparison could not be established among the years.

*Table 5. Groundwater level fluctuation in the buffer zone and trend based on pre and post monsoon water table data observed in year 2023.*

| S.No. | Site Code | Latitude | Longitude | PreM | Post M | Fluctuation | Trend |
|---|---|---|---|---|---|---|---|
| **1** | KHR-4 | 22.068803 | 75.862023 | NA | 8.68 | - | - |
| **2** | KHR-5 | 22.12494 | 75.8952 | 2.2 | 1.1 | 1.1 | Rise |
| **3** | KHR-5A | 22.12407 | 75.89518 | 3.6 | 2.25 | 1.35 | Rise |
| **4** | KHR-6A | 22.12545 | 75.84165 | NA | 1.02 | - | - |
| **5** | KHR-7A | 22.12314 | 75.7963 | 6.6 | 5 | 1.6 | Rise |
| **6** | KHR-7B | 22.12126 | 75.79317 | 6.78 | 5.2 | 1.58 | Rise |
| **7** | KHR-8A | 22.10271 | 75.75548 | NA | 1.09 | - | - |
| **8** | KHR-10A | 22.04086 | 75.81116 | NA | 1.8 | - | - |
| **9** | KHR-13 | 22.06608 | 75.87139 | 7.9 | Discarded | - | - |
| **10** | KHR-15A | 22.07092 | 75.85599 | 1.55 | 1.78 | -0.23 | fall |
| **11** | KHR-16A | 22.07912 | 75.80412 | 12.4 | Discarded | - | - |
| **12** | KHR-18 | 22.06295 | 75.85256 | 4.56 | 4.1 | 0.46 | Rise |
| **13** | KHR-20A | 22.0833 | 75.8515 | 1.5 | 1.1 | 0.4 | Rise |
| **14** | KHR-21 | 22.12321 | 75.90812 | 5.2 | 3.38 | 1.82 | Rise |
| **15** | KHR-22 | 22.11305 | 75.92877 | 5.4 | 1.22 | 4.18 | Rise |
| **16** | KHR-23 | 22.10902 | 75.93549 | 2.3 | 1.42 | 0.88 | Rise |
| **17** | KHR-24 | 22.04485 | 75.87855 | 9 | 0.3 | 8.7 | Rise |
| **18** | KHR-25 | 22.02839 | 75.89527 | NA | 2 | - | - |
| **19** | KHR-26 | 21.99242 | 75.86363 | 2.9 | 2.62 | 0.28 | Rise |
| **20** | KHR-27 | 22.00855 | 75.90918 | NA | 2.6 | - | - |
| **21** | KHR-28 | 21.97891 | 75.86348 | NA | 1.2 | - | - |
| **22** | KHR-29 | 22.02219 | 75.87928 | NA | 1.2 | - | - |
| **23** | KHR-30 | 22.04405 | 75.85148 | NA | 1.3 | - | - |
| **24** | KHR-31 | 22.065 | 75.88535 | NA | 2 | - | - |
| **25** | KHR-32 | 22.10956 | 75.96084 | NA | 1.3 | - | - |
| **26** | KHR-Pz1 | 22.07826 | 75.8367 | 2.7 | 2.1 | 0.6 | Rise |
| **27** | KHR-Pz2 | 22.07721 | 75.83306 | 12.33 | 9.27 | 3.06 | Rise |
| **28** | KHR-Pz3 | 22.07476 | 75.83177 | 3.3 | 2.42 | 0.88 | Rise |
| **29** | KHR-Pz4 | 22.07289 | 75.83233 | 3.5 | 1.2 | 2.3 | Rise |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **30** | KHR-Pz5 | 22.07055 | 75.83277 | 9.4 | 7.1 | 2.3 | Rise |
| **31** | KHR-Pz6 | 22.07089 | 75.83548 | 9.5 | 5.5 | 4 | Rise |

*Table 6. Groundwater level fluctuation in the buffer zone and trend based secondary data collected in year 2018 during pre and post monsoon period.*

| S.No. | Site | Latitude | Longitude | PreM | PosM | Fluctuation | Trend |
|---|---|---|---|---|---|---|---|
| 1 | Amba | 75.94472 | 22.0434 | 20.192 | 3.392 | 16.8 | Rise |
| 2 | Dabhad | 75.90045 | 22.06681 | 26.234 | 8.934 | 17.3 | Rise |
| 3 | Dalchi | 75.82992 | 22.07724 | 38.317 | 16.817 | 21.5 | Rise |
| 4 | Bhatyan Khurd | 75.76541 | 22.05257 | 26.288 | 7.888 | 18.4 | Rise |
| 5 | Pipalgon | 75.7546 | 22.10257 | 26.027 | 5.327 | 20.7 | Rise |
| 6 | Londhi | 75.79397 | 22.12351 | 21.228 | 3.828 | 17.4 | Rise |
| 7 | Kanapur | 75.84291 | 22.12278 | 24.51 | 3.71 | 20.8 | Rise |
| 8 | Badgaon | 75.89517 | 22.125 | 19.947 | 1.447 | 18.5 | Rise |
| 9 | Satkhali | 75.88277 | 21.99955 | 49.277 | 24.577 | 24.7 | Rise |
| 10 | Padliya Gawli | 75.85117 | 22.00762 | 23.197 | 5.597 | 17.6 | Rise |
| 11 | Ahirkheda | 75.86368 | 21.97928 | 26.463 | 9.163 | 17.3 | Rise |
| 12 | Umariya | 75.89675 | 22.02771 | 34.067 | 14.067 | 20 | Rise |
| 13 | Bhopada | 75.81374 | 22.0421 | 27.499 | 5.499 | 22 | Rise |
| 14 | Khedi Buzurg | 75.87746 | 22.04958 | 29.144 | 14.344 | 14.8 | Rise |
| 15 | Bakava | 75.85374 | 22.16816 | 26.807 | 9.107 | 17.7 | Rise |
| 16 | Bhatud | 75.93065 | 22.10305 | 30.998 | 0.798 | 30.2 | Rise |
| 17 | Peer Baba Mazar | 75.83866 | 22.1375 | 24.489 | 6.089 | 18.4 | Rise |
| 18 | Lachhora | 75.92346 | 22.07634 | 22.696 | 3.696 | 19 | Rise |
| 19 | Pokhar | 75.83076 | 21.99802 | 24.14 | 6.34 | 17.8 | Rise |
| 20 | Sala Khurd | 75.87948 | 22.02154 | 38.346 | 17.146 | 21.2 | Rise |
| 21 | Dudgaon | 75.945 | 22.1024 | 18.934 | 2.434 | 16.5 | Rise |
| 22 | Kharadi | 75.84705 | 22.02258 | 47.172 | 8.072 | 39.1 | Rise |
| 23 | Mardaliya | 75.95227 | 22.0791 | 48.978 | 3.078 | 45.9 | Rise |
| 24 | Bet Dabhad-Selda | 75.88542 | 22.065 | 25.68 | 12.48 | 13.2 | Rise |
| 25 | Plant Area | 75.862 | 22.06884 | 21.856 | 8.656 | 13.2 | Rise |

## 5.4 *Estimated Contribution of Rain water harvesting done at NTPC plant to the ground water recharge*

The comprehensive assessment of rainwater harvesting potential across different areas, as outlined in the report from the National Institute of Hydrology (NIH) in 2018, revealed an intricate understanding of the catchment type, climatic conditions, and surface characteristics. The calculated potential for rainwater harvesting from the main plant area, township, and green belt regions, amounting to 0.794 million cubic meters (MCM), for enrichment of water resources of nearby plant area.

As a contribution to this an initiative has been undertaken at the NTPC plant in Khargone, specifically addressing the impact on groundwater recharge. NTPC has implemented a rainwater harvesting system, consisting of 44 recharge pits strategically installed within the main plant premises. These pits are designed to

capture rainwater from various sources, including rooftop surfaces, open areas, and stormwater runoff. The rainwater collected from these sources is directed into the recharge pits, facilitating the infiltration of water to the underlying groundwater resource. This process contributes to the recharge of subsurface unconfined aquifers, enhancing the overall groundwater levels in the region. The collective recharge capacity of these 44 pits is specified as 0.36 million cubic meters (MCM). However, the successful implementation of the rainwater harvesting system at the NTPC plant in Khargone, coupled with the insights gained from the comprehensive assessment by NIH Roorkee in 2018, paves the way for further impactful contributions to water resource enrichment. The calculated potential of 0.794 million cubic meters (MCM) highlights the substantial capacity for rainwater harvesting across the main plant area, township, and green belt regions. Indeed, there is a scope for expanding and improving the existing rainwater harvesting structures and methodologies. This could involve identifying additional strategic locations for recharge pits, optimizing capture mechanisms, and implementing advanced technologies for efficient rainwater utilization. Furthermore, ongoing monitoring and periodic reassessments of rainwater harvesting potential will enable adaptive strategies, ensuring continuous improvement and resilience in addressing local water needs.

# 6 SURFACE WATER QUALITY AT IDENTIFIED LOCATIONS AND CURRENT SOURCES OF CONTAMINATION, IF ANY.

The team visited KhSTPS Khargone during April 25 – 30, 2023, to undertake a pre-monsoon survey and collection of surface water samples in 10 km buffer zone from the power station area, ash dyke and surrounding. During the site survey, the team identified several observation points for data collection of surface water within a 10 km radius of the power station area.

## *6.1 Surface Water Quality during Pre-monsoon 2023 season*

Surface water samples were collected from identified locations to identify the current sources of contamination, if any. Salient details such as sample code, station name,

location, and type of analysis for which surface water sample is collected during the pre-monsoon 2023 visit are listed in *Table 7*. The geographical location of surface water sampling points for pre-monsoon 2023 sampling points is shown in *Figure 12*. The collected samples were analysed for required water quality parameters. COD and BOD are measured through the oxidation-titration method. In the In-situ analysis of the samples, pH, TDS (Total dissolved solids), EC (Electrical Conductivity), DO (Dissolved Oxygen), and temperature were measured at the water collection site using a multi-meter electrode. Measured values of physical parameters like DO, TDS, EC, pH, Temperature, COD, BOD, and Hardness (COD, BOD, Hardness, DO, and TDS in mg/L; EC in mS/cm; pH in the standard unit and temperature in *°C*) during the pre-monsoon season are listed in *Table 8*.

The pH values ranged from 6.86 to 8.58, with a mean value of 7.9. The sample collected from the Ambak reservoir has the highest pH level, i.e., 8.58. TDS concentrations ranged from 120 mg/L to 570 mg/L, with an average value of 287.9 mg/L. DO concentrations ranged from 3.8 mg/L to 15 mg/L, with a mean value of 7.2 mg/L. The EC concentration ranged from 0.25 ms/cm to 1.16 ms/cm, with an average value of 0.6 ms/cm. Hardness ranged from 162.9 mg/L to 625.1 mg/L in the pre-monsoon 2023 period, with an average value of 321.4 mg/L. COD and BOD are also determined in surface water samples during the pre-monsoon season, where the BOD ranged from 4 mg/L to 16 mg/L with a mean value of 10.1mg/L while COD ranged from 36 mg/L to 112 mg/L with an average of 66.4 mg/L. The temperature of the surface water samples ranged from 27.1°C to 34.2°C with a mean value of 30.5°C.

*Table 7. Surface water sampling sites in a 10 km buffer (pre-monsoon 2023)*

| S.No | Code | Latitude | Longitude | Station Name | Type of Analysis | Type of Site |
|---|---|---|---|---|---|---|
| 1 | KHR-51 | 22.07047 | 75.858149 | Pond Between NTPC Power station & Township | In-situ and Ex-situ | Surface water |
| 2 | KHR-52 | 22.12206 | 75.842803 | Near Health Centre along Main road, Vill Kanapur | In-situ and Ex-situ | Surface water |
| 3 | KHR-53 | 22.104185 | 75.812277 | Jirbhar lake | In-situ and Ex-situ | Surface water |
| 4 | KHR-54A | 22.158804 | 75.76167 | Narmada River Downstream | In-situ and Ex-situ | Surface water |
| 5 | KHR-55 | 22.006354 | 75.848828 | Ambak Resevoir | In-situ and Ex-situ | Surface water |
| 6 | KHR-56 | 22.075493 | 75.927687 | Lachhora Talab | In-situ and Ex-situ | Surface water |
| 7 | KHR-57 | 22.115246 | 75.866087 | Kattora Pond, Shelda Power station-Kattora Road | In-situ and Ex-situ | Surface water |
| 8 | KHR-58 | 22.07323 | 75.833941 | OFL Ash Dyke | In-situ and Ex-situ | Surface water |
| 9 | KHR-59 | 22.073978 | 75.839568 | Lagoon 1 Ash Dyke | Dried up | Surface water |
| 10 | KHR-60 | 22.07661 | 75.8332 | Lagoon 2 Ash Dyke | In-situ and Ex-situ | Surface water |
| 11 | KHR-61 | 22.06741 | 75.860638 | Raw water reservoir inside power station | In-situ and Ex-situ | Surface water |
| 12 | KHR-61Ae | 22.063462 | 75.855098 | Aerated water from raw water reservoir | In-situ and Ex-situ | Surface water |

| | | | | | | |
|---|---|---|---|---|---|---|
| 13 | KHR-62 | 22.07441 | 75.850902 | Below tower line on road crossing near power station | In-situ and Ex-situ | Surface water |
| 14 | KHR-63 | 22.1927 | 75.97763 | Narmada River upstream, Toksar | In-situ and Ex-situ | Surface water |
| 15 | KHR-64 | 22.00772 | 75.90917 | Ambak River, Khargone-Sanawad road | In-situ and Ex-situ | Surface water |

*Table 8. Physical parameters in surface water samples during the pre-monsoon season of April (2023); pH in standard units.*

| S.No. | Code | DO (mg/L) | TDS (mg/L) | EC mS/cm) | pH (Range) | Temp (°C) | BOD (mg/L) | COD (mg/L) | Hardness (mg/L) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | KHR-51 | 9.62 | 400 | 0.81 | 8.45 | 34.2 | 9 | 39 | 532 |
| 2 | KHR-52 | 15+ | 450 | 0.9 | 8.45 | 32.5 | 14 | 103 | 401 |
| 3 | KHR-53 | 3.78 | 300 | 0.61 | 7.66 | 28.4 | 15 | 68 | 400 |
| 4 | KHR-54A | 6.36 | 140 | 0.29 | 6.86 | 29.8 | 6 | 65 | 193 |
| 5 | KHR-55 | 8.48 | 120 | 0.25 | **8.58** | 32.3 | 9 | 52 | 172 |
| 6 | KHR-56 | 5.28 | 220 | 0.45 | 8.12 | 30.2 | 6 | 59 | 281 |
| 7 | KHR-57 | 6.46 | 160 | 0.33 | 8.08 | 32.9 | 10 | 66 | 215 |
| 8 | KHR-58 | 7.04 | 570 | 1.16 | 8.06 | 30 | 16 | 48 | 300 |
| 9 | KHR-59 | | | | **Dried** | | | | |
| 10 | KHR-60 | 7.02 | 540 | 1.08 | 8.32 | 29.7 | 14 | 65 | 392 |
| 11 | KHR-61 | 5.85 | 130 | 0.27 | 8.2 | 28.6 | 7 | 41 | 163 |
| 12 | KHR-61Ae | 8.3 | 160 | 0.33 | 7.87 | 28.7 | 4 | 36 | 203 |
| 13 | KHR-62 | 5.98 | 470 | 0.95 | 7.45 | 32.9 | 14 | 112 | 625 |
| 14 | KHR-63 | 7.3 | 150 | 0.32 | 7.72 | 27.1 | 9 | 84 | 222 |
| 15 | KHR-64 | 4.82 | 220 | 0.44 | 7.44 | 30 | 8 | 91 | 401 |
| **BIS Limits** | **AL** | **NS** | **500** | **NS** | **6.5-8.5** | **NS** | **NS** | **NS** | **200** |
| | **PL** | | **2000** | | **NR** | | | | **600** |

*Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL-Permissible Limit; BDL: Below detection limit*

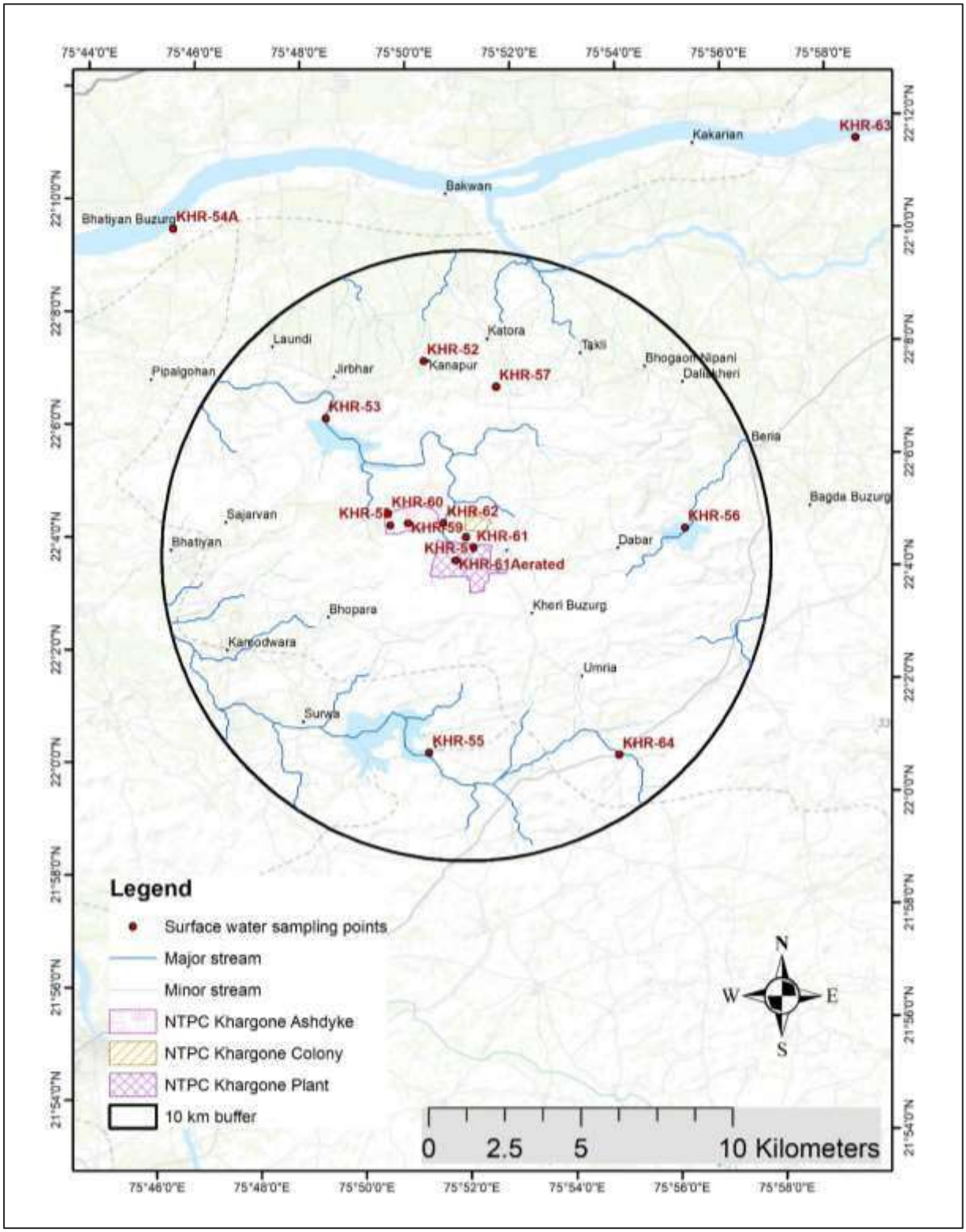


*Figure 12. Map depicting the location of surface water sampling points during pre-monsoon 2023.*

The mean concentration of heavy metals in the collected surface water samples and their comparison with BIS limits 10500:2012 during the pre-monsoon season (April 2023) is listed in Table 9. The concentration of arsenic (As) ranged from 0.005 ppm to 0.02 ppm, with an average value of 0.008 ppm. Pb concentration varied between 0.001-0.002 ppm with an almost insignificant mean value. The concentration of Cd, Cr, Cu, Zn, Se, and Fe ranged between 0.0003- 0.0004 ppm, 0.006-0.011 ppm, 0.031-0.043 ppm, 0.062-0.105 ppm, BDL-0.014, 0.1-2.1, respectively. Mercury (Hg) was below detectable limits in the surface water samples in the pre-monsoon 2023 period.

*Table 9. Mean concentration (in ppm) of heavy metals in the surface water samples and their comparison with BIS limits 10500:2012 during pre-monsoon season of April (2023)*

| S.No. | Code | As | Hg | Pb | Cd | Cr | Cu | Zn | Se | Fe |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | KHR-51 | 0.006 | BDL | 0.001 | 0.0004 | 0.01 | 0.04 | 0.08 | 0.001 | **1.1** |
| 2 | KHR-52 | 0.009 | BDL | 0.002 | 0.0003 | 0.01 | 0.04 | 0.08 | 0.002 | **1.2** |
| 3 | KHR-53 | 0.008 | BDL | 0.002 | 0.0003 | 0.01 | 0.04 | 0.11 | BDL | 0.1 |
| 4 | KHR-54 | 0.006 | BDL | 0.001 | 0.0003 | 0.01 | 0.03 | 0.08 | 0.002 | 0.1 |
| 5 | KHR-55 | 0.007 | BDL | 0.002 | 0.0004 | 0.01 | 0.04 | 0.09 | 0.001 | 0.1 |
| 6 | KHR-56 | 0.008 | BDL | 0.002 | 0.0003 | 0.01 | 0.04 | 0.10 | 0.001 | **0.5** |
| 7 | KHR-57 | 0.005 | BDL | 0.001 | 0.0003 | 0.01 | 0.03 | 0.08 | BDL | **0.4** |
| 8 | KHR-58 | 0.014 | BDL | 0.002 | 0.0003 | 0.01 | 0.04 | 0.06 | 0.011 | 0.1 |
| 9 | KHR-59 | | | | | **Dried** | | | | |
| 10 | KHR-60 | **0.020** | BDL | 0.002 | 0.0003 | 0.01 | 0.04 | 0.09 | **0.014** | **2.1** |
| 11 | KHR-61 | 0.007 | BDL | 0.001 | 0.0003 | 0.01 | 0.04 | 0.09 | 0.001 | 0.1 |
| 12 | KHR-61Ae | 0.007 | BDL | 0.002 | 0.0004 | 0.01 | 0.04 | 0.07 | 0.001 | 0.1 |
| 13 | KHR-62 | 0.007 | BDL | 0.001 | 0.0003 | 0.01 | 0.03 | 0.09 | 0.003 | 0.1 |
| 14 | KHR-63 | 0.007 | BDL | 0.002 | 0.0003 | 0.01 | 0.04 | 0.08 | 0.002 | 0.1 |
| 15 | KHR-64 | 0.006 | BDL | 0.001 | 0.0003 | 0.01 | 0.03 | 0.08 | 0.001 | 0.5 |
| **BIS (IS:10500-2012)** | **AL** | **0.01** | **0.001** | **0.01** | **0.003** | **0.05** | **0.05** | **5** | **0.01** | **0.3** |
| | **PL** | **0.05** | **NR** | **NR** | **NR** | **NR** | **1.5** | **15** | **NR** | **NR** |

*Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL-Permissible Limit; BDL: Below detection limit*

Ion Chromatography (IC) analysis was performed to measure the concentration of anions such as nitrate ($NO_3^-$), phosphate ($PO_4^-$), chloride ($Cl^-$), fluoride ($F^-$), bromide ($Br^-$) and sulfate ($SO_4^{2-}$). Prior to IC analysis, samples were diluted to a suitable degree with MQ water. After that, the samples were filtered through a 0.2µm filter before their analysis. Moreover, cations such as calcium ($Ca^{2+}$), magnesium ($Mg^{2+}$), sodium ($Na^+$), and potassium ($K^+$) were measured using MPAES at the Institute Instrumentation

Center (IIC) of IIT Roorkee. The concentrations of major ions in surface water samples and their comparison with BIS limits is listed in Table 10. In the pre-monsoon 2023 season, $F^-$ concentration ranges between 0.2-3.1 mg/L with an average value of 0.7 mg/L. The concentration of $Cl^-$ ranged from 7.9 to 91.9 mg/L, with an average value of 36.3 mg/L. The concentration of $NO_3^-$ ranged from BDL to 25.6 mg/L, with an average value of 4.5 mg/L. $SO_4^{2-}$ levels ranged from 15.3 to 942.3 mg/L with an average value of 185.9 mg/L. $Ca^{2+}$ levels ranged from 40.1 mg/L to 190.8 mg/L, with an average value of 79.2 mg/L. The concentration of $K^+$ ranged from 1.8 mg/L to 97.6 mg/L with an average value of 11.7 mg/L. The concentration of $Mg^{2+}$ ranged from 11.4 mg/L to 57.5 mg/L with an average value of 30.1 mg/L. $Na^+$ level ranged from 21.5 mg/L to 142.7 mg/L with an average value of 59.1 mg/L. The $HCO_3$ concentration ranged from 101 mg/L to 542 mg/L, with an average value of 205.5 mg/L.

*Table 10. Mean concentration (in mg/L) of major ions in surface water samples and their comparison with BIS limits of IS 10500:2012 during pre-monsoon season of April (2023)*

| Sr. No. | Code | $F^-$ | $Cl^-$ | $Br^-$ | $NO_3^-$ | $PO_4^-$ | $SO_4^{2-}$ | $Ca^{2+}$ | $K^+$ | $Mg^{2+}$ | $Na^+$ | $HCO_3^-$ | $CO_3^-$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | KHR-51 | 0.4 | 85.3 | ND | 1.8 | ND | 304.5 | 118.3 | 9.0 | 57.5 | 99.9 | 175 | ND |
| 2 | KHR-52 | 0.4 | 90.1 | ND | 1.0 | ND | 67.4 | 74.8 | 97.6 | 51.9 | 142.7 | 365 | ND |
| 3 | KHR-53 | 0.4 | 31.2 | ND | 8.6 | ND | 128 | 100.9 | 4.0 | 36.1 | 58.4 | 154 | ND |
| 4 | KHR-54 | 0.2 | 10 | ND | 2.7 | ND | 15.3 | 56.7 | 3.6 | 12.5 | 25.2 | 193 | ND |
| 5 | KHR-55 | 0.3 | 7.9 | ND | 1.5 | ND | 19.5 | 43.1 | 2.7 | 15.6 | 26.6 | 159 | ND |
| 6 | KHR-56 | 0.5 | 20.6 | ND | 3.5 | ND | 57.3 | 61.0 | 4.1 | 31.2 | 57.6 | 542 | ND |
| 7 | KHR-57 | 0.5 | 8.9 | ND | 4.0 | ND | 26.8 | 57.9 | 2.3 | 17.1 | 28.8 | 210 | ND |
| 8 | KHR-58 | **3.1** | 77.0 | ND | 3.2 | ND | **942.3** | 40.1 | 13.3 | 48.6 | 87.8 | 112 | ND |
| 9 | KHR-59 | **DRIED** | | | | | | | | | | | |
| 10 | KHR-60 | **2.3** | 37.5 | ND | 1.6 | ND | **566.9** | 75.4 | 14.7 | 49.4 | 91.2 | 101 | ND |
| 11 | KHR-61 | 0.3 | 8.7 | ND | BDL | ND | 29.1 | 46.4 | 2.0 | 11.4 | 31.8 | 153 | ND |
| 12 | KHR-61Ae | 0.3 | 8.7 | ND | BDL | ND | 22.1 | 58.9 | 2.6 | 13.6 | 21.5 | 136 | ND |
| 13 | KHR-62 | 0.5 | 91.9 | ND | 7.8 | ND | 378 | 190.8 | 1.8 | 36.1 | 88.5 | 182 | ND |
| 14 | KHR-63 | 0.3 | 9.1 | ND | 2.1 | ND | 15.5 | 66.5 | 2.9 | 13.6 | 26.5 | 210 | ND |
| 15 | KHR-64 | 0.5 | 21 | ND | 25.6 | ND | 29.5 | 117.5 | 3.0 | 26.0 | 40.2 | 185 | ND |
| **BIS limits (IS:10500-2012)** | **AL** | **1** | **250** | **NS** | **45** | **NS** | **200** | **75** | **NS** | **30** | **NS** | **NS** | **NS** |
| | **PL** | **1.5** | **1000** | | **NR** | | **400** | **200** | | **100** | | | |

*Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL- Permissible Limit; BDL: Below detection limit*

## 6.2 *Surface Water Quality during Post-monsoon 2023 season*

Surface water samples were collected from identified locations to identify the current sources of contamination in post monsoon season. Salient details such as sample code, station name, location, and type of analysis for which surface water samples were collected during the post-monsoon 2023 visit are listed in *Table 7*. The collected samples were analysed for required surface water quality parameters. Measured values of physical parameters like DO, TDS, EC, pH, Temperature, along with COD, BOD, and Hardness (in mg/L) else EC in mS/cm; pH in the standard unit and temperature in *°C*, during the pre-monsoon season are listed in *Table 8*.

*Table 11. Surface water sampling sites in a 10 km buffer (post-monsoon 2023)*

| S.No | Code | Latitude | Longitude | Station Name | Type of Analysis | Type of Site |
|---|---|---|---|---|---|---|
| 1 | KHR-51 | 22.07047 | 75.858149 | Pond Between NTPC Power station & Township | In-situ and Ex-situ | Surface water |
| 2 | KHR-52 | 22.12206 | 75.842803 | Near Health Centre along Main road, Vill Kanapur | In-situ and Ex-situ | Surface water |
| 3 | KHR-53 | 22.104185 | 75.812277 | Jirbhar lake | In-situ and Ex-situ | Surface water |
| 4 | KHR-54A | 22.158804 | 75.76167 | Narmada River Downstream | In-situ and Ex-situ | Surface water |
| 5 | KHR-55 | 22.006354 | 75.848828 | Ambak Resevoir | In-situ and Ex-situ | Surface water |
| 6 | KHR-56 | 22.075493 | 75.927687 | Lachhora Talab | In-situ and Ex-situ | Surface water |
| 7 | KHR-57 | 22.115246 | 75.866087 | Kattora Pond, Shelda Power station-Kattora Road | In-situ and Ex-situ | Surface water |
| 8 | KHR-58 | 22.07323 | 75.833941 | OFL Ash Dyke | In-situ and Ex-situ | Surface water |
| 9 | KHR-59 | 22.073978 | 75.839568 | Lagoon 1 Ash Dyke | Dried up | Surface water |
| 10 | KHR-60 | 22.07661 | 75.8332 | Lagoon 2 Ash Dyke | In-situ and Ex-situ | Surface water |
| 11 | KHR-61 | 22.06741 | 75.860638 | Raw water reservoir inside power station | In-situ and Ex-situ | Surface water |
| 12 | KHR-62 | 22.07441 | 75.850902 | Below tower line on road crossing | In-situ and Ex-situ | Surface water |
| 13 | KHR-63 | 22.1927 | 75.97763 | Narmada River upstream, Toksar | In-situ and Ex-situ | Surface water |
| 14 | KHR-64 | 22.00772 | 75.90917 | Ambak River, Khargone-Sanawad road | In-situ and Ex-situ | Surface water |

The pH values ranged from 6.94 to 8.32, with a mean value of 7.75. TDS concentrations ranged from 100 mg/L to 970 mg/L, with an average value of 337.69 mg/L. DO concentrations ranged from 3.8 mg/L to 10.08 mg/L, with a mean value of 7.41 mg/L. The EC concentration ranged from 0.21 ms/cm to 1.94 ms/cm, with an average value of 0.69 ms/cm. Hardness ranged from 84.42 mg/L to 338.50 mg/L in the post-monsoon period, with an average value of 168.50 mg/L. COD and BOD are also determined in surface water samples during the post-monsoon season, where the BOD ranged from 4 mg/L to 14 mg/L with a mean value of 8.38 mg/L while COD ranged from 26 mg/L to 111 mg/L with an average of 56.46 mg/L. The temperature of the surface water samples ranged from 26.70°C to 32.45°C with a mean value of 30.16°C.

*Table 12. Physical parameters in surface water samples during the post-monsoon season of 2023; pH in standard units.*

| S.No. | Code | DO (mg/L) | TDS (mg/L) | EC (mS/cm) | pH (Range) | Temp (°C) | BOD (mg/L) | COD (mg/L) | Hardness (mg/L) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | KHR-51 | 9.53 | 410 | 0.86 | 8.32 | 32.45 | 5 | 26 | 91 |
| 2 | KHR-52 | 7.87 | 240 | 0.5 | 7.75 | 30.9 | 11 | 111 | 161 |
| 3 | KHR-53 | 3.8 | 150 | 0.31 | 7.63 | 26.7 | 9 | 70 | 127 |
| 4 | KHR-54A | 7.23 | 160 | 0.32 | 6.94 | 27.3 | 5 | 60 | 135 |
| 5 | KHR-55 | 8.74 | 220 | 0.45 | 7.89 | 32.2 | 10 | 35 | 155 |
| 6 | KHR-56 | 10.08 | 130 | 0.26 | 8.12 | 29.2 | 4 | 33 | 84 |
| 7 | KHR-57 | 7.57 | 120 | 0.24 | 7.99 | 30.7 | 12 | 41 | 106 |
| 8 | KHR-58 | 7.2 | 970 | 1.95 | 7.51 | 30.4 | 14 | 46 | 262 |
| 9 | KHR-59 | | | | **DRIED** | | | | |
| 10 | KHR-60 | 7.21 | 970 | 1.95 | 7.66 | 30.5 | 10 | 56 | 338 |
| 11 | KHR-61 | 6.2 | 100 | 0.21 | 8.27 | 31.7 | 9 | 39 | 88 |
| 12 | KHR-62 | 6.32 | 410 | 0.83 | 7.43 | 29.6 | 6 | 92 | 320 |
| 13 | KHR-63 | 6.5 | 230 | 0.47 | 7.41 | 29.3 | 5 | 67 | 210 |
| 14 | KHR-64 | 8.09 | 280 | 0.57 | 7.8 | 31.1 | 9 | 58 | 113 |
| **BIS Limits** | **AL** | **NS** | **500** | **NS** | **6.5-8.5** | **NS** | **NS** | **NS** | **200** |
| | **PL** | | **2000** | | **NR** | | | | **600** |

*Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL-Permissible Limit; BDL: Below detection limit*

The mean concentration of heavy metals in the collected surface water samples and their comparison with BIS limits is listed in Table 9. The concentration of arsenic (As) ranged from 0.001 ppm to 0.004 ppm, with an average value of 0.001 ppm. Pb concentration varied between 0.002-0.007 ppm with an almost insignificant mean value of 0.003. The concentration of Cd, Cr, Cu, Se, and Fe ranged between 0.001- 0.002 ppm, 0.018-0.023 ppm, 0.003-0.150 ppm, BDL-0.010, 0.15-0.37, respectively.

*Table 13. Mean concentration (in ppm) of heavy metals in the surface water samples and their comparison with BIS limits 10500:2012 during post-monsoon season of 2023*

| S.No. | Code | As | Hg | Pb | Cd | Cr | Cu | Zn | Se | Fe |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | KHR-51 | **0.001** | **ND** | 0.002 | **0.002** | **0.02** | **ND** | **ND** | **BDL** | **0.18** |
| 2 | KHR-52 | **0.001** | **ND** | 0.007 | **0.002** | **0.02** | **0.01** | **ND** | **BDL** | **0.31** |
| 3 | KHR-53 | **0.001** | **ND** | 0.003 | **0.002** | **0.02** | **0.01** | **ND** | **BDL** | **0.25** |
| 4 | KHR-54 | **0.001** | **ND** | 0.003 | **0.001** | **0.02** | **0.01** | **ND** | **BDL** | **0.37** |
| 5 | KHR-55 | **0.001** | **ND** | 0.003 | **0.002** | **0.02** | **0.15** | **ND** | **BDL** | **0.23** |
| 6 | KHR-56 | **0.001** | **ND** | 0.004 | **0.002** | **0.02** | **ND** | **ND** | **BDL** | **0.20** |
| 7 | KHR-57 | **0.001** | **ND** | 0.002 | **0.001** | **0.02** | **0.01** | **ND** | **BDL** | **0.21** |
| 8 | KHR-58 | **0.003** | **ND** | 0.002 | **0.002** | **0.02** | **ND** | **ND** | **0.01** | **0.18** |
| 9 | KHR-59 | | | | | **DRIED** | | | | |
| 10 | KHR-60 | **0.004** | **ND** | 0.002 | **0.002** | **0.02** | **ND** | **ND** | **0.01** | **0.18** |
| 11 | KHR-61 | **0.001** | **ND** | 0.003 | **0.002** | **0.02** | **0.01** | **ND** | **BDL** | **0.23** |
| 12 | KHR-62 | **0.001** | **ND** | 0.002 | **0.002** | **0.02** | **ND** | **ND** | **BDL** | **0.20** |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 13 | KHR-63 | **0.001** | **ND** | 0.002 | **0.002** | **0.02** | **0.01** | **ND** | **BDL** | **0.18** |
| 14 | KHR-64 | **0.001** | **ND** | 0.002 | **0.001** | **0.02** | **0.01** | **ND** | **BDL** | **0.15** |
| **BIS (IS:10500-2012)** | **AL** | **0.01** | **0.001** | **0.01** | **0.003** | **0.05** | **0.05** | **5** | **0.01** | **0.3** |
| | **PL** | **0.05** | **NR** | **NR** | **NR** | **NR** | **1.5** | **15** | **NR** | **NR** |

*Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL-Permissible Limit; BDL: Below detection limit*

The concentrations of major ions in surface water samples and their comparison with BIS limits for the post-monsoon season of 2023 is listed in Table 10. In the post-monsoon season, $F^-$ concentration ranges between 0.3-8.4 mg/L with an average value of 1.2 mg/L. The concentration of $Cl^-$ ranged from 30 to 280 mg/L, with an average value of 124.6 mg/L. The concentration of $NO_3^-$ ranged from 1.6 to 6.7 mg/L, with an average value of 3.9 mg/L. $SO_4^{2-}$ levels ranged from 6 to 386.2 mg/L with an average value of 80.4 mg/L. $Ca^{2+}$ levels ranged from 15.75 mg/L to 81.45 mg/L, with an average value of 33.31 mg/L. The concentration of $K^+$ ranged from 0.04 mg/L to 3.07 mg/L with an average value of 0.5 mg/L. The concentration of $Mg^{2+}$ ranged from 9.75 mg/L to 82.2 mg/L with an average value of 24.9 mg/L. $Na^+$ level ranged from 31.5 mg/L to 185.1 mg/L with an average value of 78.98 mg/L. The $HCO_3^-$ concentration ranged from 105 mg/L to 450 mg/L, with an average value of 201.2 mg/L.

*Table 14. Mean concentration (in mg/L) of major ions in surface water samples and their comparison with BIS limits of IS 10500:2012 during post-monsoon season of 2023*

| Sr. No. | Code | $F^-$ | $Cl^-$ | $Br^-$ | $NO_3^-$ | $PO_4^-$ | $SO_4^{2-}$ | $Ca^{2+}$ | $K^+$ | $Mg^{2+}$ | $Na^+$ | $HCO_3^-$ | $CO_3^-$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | KHR-51 | 0.5 | 80 | ND | 1.6 | ND | 22.3 | 20.4 | 0.06 | 9.75 | 31.5 | 160 | ND |
| 2 | KHR-52 | 0.3 | 90 | ND | 2.0 | ND | 6 | 30.9 | 1.55 | 20.4 | 88.8 | 340 | ND |
| 3 | KHR-53 | 0.8 | 60 | ND | 2.3 | ND | 22.3 | 31.65 | 0.09 | 11.55 | 39.75 | 185 | ND |
| 4 | KHR-54 | 0.6 | 100 | ND | 5.6 | ND | 188.9 | 23.4 | 3.07 | 18.6 | 185.1 | 190 | ND |
| 5 | KHR-55 | 0.5 | 30 | ND | 6.7 | ND | 20.0 | 29.55 | 0.11 | 19.65 | 62.25 | 145 | ND |
| 6 | KHR-56 | 0.8 | 240 | ND | 2.7 | ND | 9.1 | 15.75 | 0.07 | 10.95 | 40.65 | 450 | ND |
| 7 | KHR-57 | 0.3 | 60 | ND | 3.7 | ND | 10.3 | 25.05 | 0.07 | 10.5 | 37.2 | 205 | ND |
| 8 | KHR-58 | **8.4** | 170 | ND | 2.7 | ND | 198.6 | 24.1 | 0.43 | 63.6 | 119.55 | 125 | ND |
| 9 | KHR-59 | | | | | | DRIED | | | | | | |
| 10 | KHR-60 | 0.9 | 280 | ND | 4.1 | ND | 386.2 | 65.3 | 0.65 | 82.2 | 149.25 | 105 | ND |
| 11 | KHR-61 | 0.9 | 110 | ND | 4.6 | ND | 8.0 | 18.9 | 0.1 | 9.9 | 43.35 | 165 | ND |
| 12 | KHR-61Ae | 0.6 | 200 | ND | 2.7 | ND | 90.9 | 81.45 | 0.05 | 28.35 | 99.45 | 195 | ND |
| 13 | KHR-62 | 0.5 | 90 | ND | 5.1 | ND | 17.1 | 43.2 | 0.16 | 24.75 | 91.05 | 190 | ND |
| 14 | KHR-63 | 0.5 | 110 | ND | 7.0 | ND | 65.4 | 23.4 | 0.04 | 13.35 | 38.85 | 160 | ND |
| 15 | KHR-64 | 0.5 | 80 | ND | 1.6 | ND | 22.3 | 20.4 | 0.06 | 9.75 | 31.5 | 160 | ND |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **BIS limits (IS:10500-2012)** | **AL** | **1** | **250** | **NS** | **45** | **NS** | **200** | **75** | **NS** | **30** | **NS** | **NS** | **NS** |
| | **PL** | **1.5** | **1000** | | **NR** | | **400** | **200** | | **100** | | | |

*Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL- Permissible Limit; BDL: Below detection limit*

## *6.3 **Overall Analysis of Surface Water Quality during 2023***

Overall, the water quality of most of the surface water samples were found to be well within the prescribed limits of BIS standards during the pre and post-monsoon 2023 season. The concentration of a few elements such as fluoride, sulphate and some heavy metals such as Fe, Se, and As was found to be slightly higher than the prescribed BIS limits of drinking water in ash dyke samples. They might get seep into the subsurface area and ultimately pollute the groundwater in the near future if not managed properly. Also, the pH values were slightly high in samples collected from the ash dyke area; however, the overall pH range suggests that the surface water quality is slightly of alkaline nature in the present study area.

# 7 GROUNDWATER QUALITY AT IDENTIFIED LOCATIONS AND CURRENT SOURCES OF CONTAMINATION.

Based on the reconnaissance site survey of the power station area, groundwater sampling locations were identified. The identified locations and probable sources of contamination were assessed thoroughly based on the groundwater chemical analysis of the study area. The groundwater samples were collected from existing handpumps, tube wells, piezometers and bore wells. Prior to collecting the samples, the purging of sources was performed for 10-15 minutes. Also, the sampling bottles were rinsed with the same water thrice while sampling. During the In-situ analysis of the groundwater samples, pH, TDS (Total dissolved solids), EC (Electrical Conductivity), DO (Dissolved Oxygen), and temperature was measured at the sample collection site using a multi-meter electrode. Thereafter collected water samples were brought to the groundwater laboratory of IIT Roorkee for further analysis to determine its quality for domestic purposes.

## *7.1 Groundwater Quality for Pre-monsoon 2023 season*

The groundwater sampling for the pre-monsoon season was undertaken during April 25 – 30, 2023. Salient details such as sample code, station name, location, and type of analysis for which groundwater samples were collected are given in Table 15. The geographical location of groundwater sampling points during the pre-monsoon season is shown in Figure 13.

*Table 15. Location of collected groundwater samples in the study area during the pre-monsoon period (April 2023) for In-situ/Ex-situ analyses.*

| S.No. | Code | Latitude | Longitude | Station Name | Type of Analysis | Type of Site |
|---|---|---|---|---|---|---|
| **1** | KHR-1 | 22.07775 | 75.83155 | Vill. Dalchi | In-situ and Ex-situ | Hand pump |
| **2** | KHR-2 | 22.0609 | 75.7653 | Vill. Bhatyaan Khurd | In-situ and Ex-situ | Hand pump |
| **3** | KHR-3 | 22.06926 | 75.85789 | Near NTPC opp Bhilal Baba Temple, Gate No. 1 | In-situ and Ex-situ | Hand pump |
| **4** | KHR-4 | 22.0688 | 75.86202 | Between NTPC & Township | In-situ and Ex-situ | Hand pump |
| **5** | KHR-5 | 22.12494 | 75.8952 | Inside Primary School, Vill Baddgaon | In-situ and Ex-situ | Hand pump |
| **6** | KHR-6 | 22.12242 | 75.84251 | Opp. Madhya Pradesh Gramin Bank, Vill Kanapur | In-situ and Ex-situ | Hand pump |
| **7** | KHR-7 | 22.1235 | 75.794 | In House of sh. Daya Ram, Vill Londhi (Jhirbar) | In-situ and Ex-situ | Hand pump |
| **8** | KHR-8A | 22.10271 | 75.75548 | Karan Gangle Handpump, Pipalgone village. | In-situ and Ex-situ | Hand pump |
| **9** | KHR-9A | 22.10857 | 75.75845 | Lokesh Rathore Tubewell, Pipalgaon | In-situ and Ex-situ | Tube well |
| **10** | KHR-10A | 22.04086 | 75.81116 | Near Roop Singh house, Bhopada | In-situ and Ex-situ | Hand pump |

| | | | | | | |
|---|---|---|---|---|---|---|
| **11** | KHR-11 | 22.00759 | 75.85122 | Near KHR 12, Hanuman Temple, Padaliya village | In-situ and Ex-situ | Hand pump |
| **12** | KHR-12 | 22.00728 | 75.85394 | Padaliya village | In-situ and Ex-situ | Hand pump |
| **13** | KHR-13 | 22.06608 | 75.87139 | Adjoining of NTPC Community Centre | In-situ and Ex-situ | Hand pump |
| **14** | KHR-14 | 22.0493 | 75.87783 | Opp Gram Panchayat office. Vill Kheri Bujurg | In-situ and Ex-situ | Hand pump |
| **15** | KHR-15 | 22.06923 | 75.85798 | Near Bhilal Baba Temple, Near NTPC Gate No. 1 | In-situ and Ex-situ | Hand pump |
| **16** | KHR-17 | 22.06947 | 75.85227 | Below Tower Line, North side of Power station, | In-situ and Ex-situ | Seepage |
| **17** | KHR-18 | 22.06295 | 75.85256 | Well inside power station | In-situ and Ex-situ | Open well |
| **18** | KHR-19 | 22.07518 | 75.82482 | Near Baba Ramdev Mandir, Dalchi | In-situ and Ex-situ | Hand pump |
| **19** | KHR-20 | 22.09205 | 75.84918 | Below Tower Line, North side of Power station, | In-situ and Ex-situ | Hand pump |
| **20** | KHR-25 | 22.02839 | 75.89527 | Rewa Gurjar Dharamshala, Umaria | In-situ and Ex-situ | Hand pump |
| **21** | KHR-Pz1 | 22.07826 | 75.8367 | Piezometer 1, Ash Dyke | In-situ and Ex-situ | Piezometer |
| **22** | KHR-Pz2 | 22.07721 | 75.83306 | Piezometer 1, Ash Dyke | In-situ and Ex-situ | Piezometer |
| **23** | KHR-Pz3 | 22.07476 | 75.83177 | Piezometer 1, Ash Dyke | In-situ and Ex-situ | Piezometer |
| **24** | KHR-Pz4 | 22.07289 | 75.83233 | Piezometer 1, Ash Dyke | In-situ and Ex-situ | Piezometer |
| **25** | KHR-Pz5 | 22.07055 | 75.83277 | Piezometer 1, Ash Dyke | In-situ and Ex-situ | Piezometer |
| **26** | KHR-Pz6 | 22.07089 | 75.83548 | Piezometer 1, Ash Dyke | In-situ and Ex-situ | Piezometer |

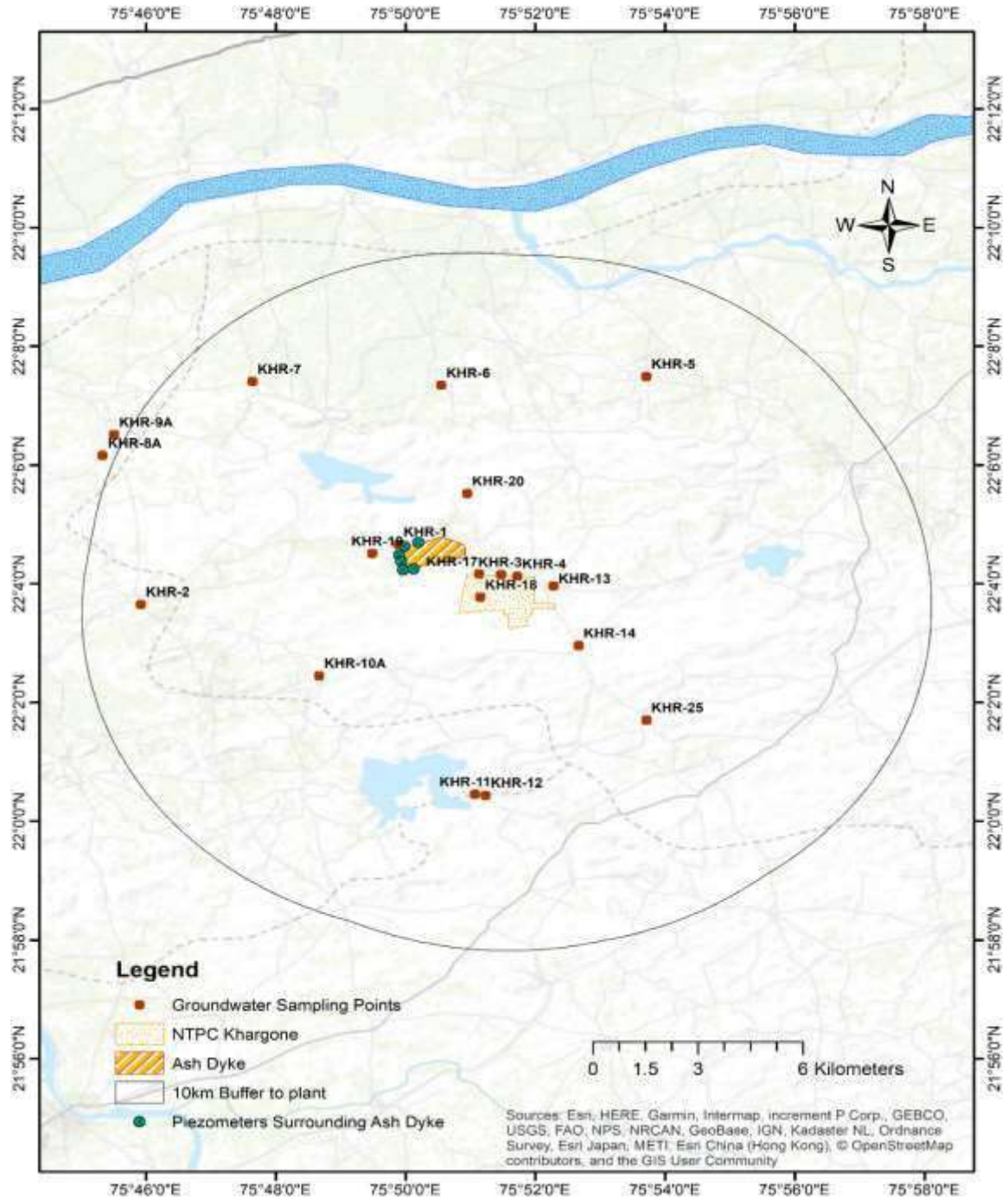


*Figure 13. Groundwater sampling points during the pre-monsoon season of year 2023.*

The mean value of in-situ parameters for the pre-monsoon period is listed in *Table 16*. The DO concentrations ranged from 1.1 mg/L to 5.9 mg/L, with a mean value of 3.2 mg/L. TDS concentrations range from 230 mg/L to 730 mg/L in the pre-monsoon period, with an average value of 466.6 mg/L. The EC concentration ranged from 470

µs/cm to 1460 µs/cm, with an average value of 940 µs/cm. The pH value ranged between 5.7-8, with an average value of 7 in the pre-monsoon period. The temperature of groundwater in pre-monsoon ranged from 28.6°C to 32.8°C with an average value of 30.5°C. The Hardness ranged from 57.6 mg/L to 789.9 mg/L in the pre-monsoon period, with an average of 511.3 mg/L.

*Table 16. Measured values of physical parameters (DO, TDS, EC, pH, Hardness and Temperature) in the groundwater samples during the pre-monsoon period from In-situ analysis.*

| S.No. | Code | DO (mg/L) | TDS (mg/L) | EC (µS/cm) | pH | Temp (°C) | Hardness |
|---|---|---|---|---|---|---|---|
| 1 | KHR-1 | 3.35 | 630 | 1260 | 6.74 | 31.3 | **657** |
| 2 | KHR-2 | 1.5 | 540 | 1090 | **5.65** | 31.7 | 433 |
| 3 | KHR-3 | 2.84 | 480 | 980 | 6.98 | 30.7 | 511 |
| 4 | KHR-4 | 5.88 | 320 | 650 | 7.16 | 28.9 | 395 |
| 5 | KHR-5 | 1.14 | 300 | 610 | 8.03 | 31 | 58 |
| 6 | KHR-6 | 2.85 | 520 | 1030 | 6.74 | 29.1 | **635** |
| 7 | KHR-7 | 1.6 | 410 | 820 | 6.91 | 29.8 | 569 |
| 8 | KHR-8A | 2.59 | 230 | 470 | 6.9 | 32.1 | 245 |
| 9 | KHR-9A | 4.29 | 410 | 840 | 6.97 | 31.3 | 325 |
| 10 | KHR-10A | 1.46 | 260 | 530 | 7.37 | 32.8 | 272 |
| 11 | KHR-11 | 3.36 | 355 | 650 | 7.23 | 32.3 | 303 |
| 12 | KHR-12 | 3.51 | 380 | 700 | 6.83 | 29.3 | 204 |
| 13 | KHR-13 | 1.41 | 440 | 880 | 6.91 | 32.4 | **606** |
| 14 | KHR-14 | 4.25 | 450 | 920 | 6.68 | 29.9 | 433 |
| 15 | KHR-15 | 3.8 | 440 | 900 | 6.98 | 31.8 | 542 |
| 16 | KHR-17 | 4.79 | 480 | 970 | 7.05 | 29.8 | **698** |
| 17 | KHR-18 | 5.58 | 690 | 1390 | 7.16 | 29 | **778** |
| 18 | KHR-19 | 1.94 | 570 | 1140 | 6.98 | 30 | 246 |
| 19 | KHR-20 | 2.8 | 390 | 800 | 6.78 | 31.8 | **623** |
| 20 | KHR-25 | 2.19 | 600 | 1210 | 6.65 | 30.1 | **790** |
| 21 | KHR-Pz1 | 4.72 | 407 | 920 | 6.98 | 28.7 | **747** |
| 22 | KHR-Pz2 | 3.03 | 620 | 1250 | 7.11 | 29.7 | **627** |
| 23 | KHR-Pz3 | 3.16 | 730 | 1460 | 7.11 | 29 | 521 |
| 24 | KHR-Pz4 | 4.36 | 430 | 870 | 7.7 | 28.6 | **723** |
| 25 | KHR-Pz5 | 2.88 | 480 | 960 | 6.64 | 30.4 | **691** |
| 26 | KHR-Pz6 | 3.82 | 570 | 1140 | 6.78 | 31.4 | **663** |
| **BIS Limits (IS:10500-2012)** | **AL**<br>**PL** | **NS** | **500**<br>**2000** | **NS** | **6.5-8.5**<br>**NR** | **NS** | **200**<br>**600** |

*Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL- Permissible Limit; BDL: Below detection limit*

Concentrations of major ions and other elements measured in groundwater samples and their comparison with BIS limits for the pre-monsoon season are shown in *Table 17*. The concentration of F- ranged from 0.3 mg/L to 3.3 mg/L, with an average value of 0.6 mg/L. Only one sample collected from inside the primary school in the village of Baddgaon showed an elevated level of fluoride. This might be due to the presence of traces of substances or minerals that include fluoride. These substances may be released into the groundwater when they are burned (coal) or dissolved (rock). The concentration of Cl- ranged from 16.4 mg/L to 125.4 mg/L, with an average value of 59.8 mg/L. NO3- levels ranged from BDL mg/L to 139.7 mg/L, with an average of 36.1 mg/L. Out of 26 samples, approximately 34% of the samples have increased nitrate levels. This could be a result of heavy usage of nitrogenous fertilisers by local farmers, which leak into the groundwater table. SO42- levels ranged from 19.6 mg/L to 996.8 mg/L, with an average of 312.7 mg/L. About 31% of the samples showed elevated levels of SO42-. This could be a result of SO42- spontaneously entering groundwater as a result of mineral disintegration from geological formations. Also, anthropogenic activities, such as the use of sulphate-based fertilisers or animal waste, can add sulphate to the soil, which eventually reaches the groundwater table through leaching or runoff might be the possible reasons of elevated SO42- concentration in the study area. In the pre-monsoon season, the Ca2+ concentration ranged from 13.6 mg/L to 241 mg/L, averaging 151.6 mg/L. Likewise, K+ concentration ranged from 0.33 mg/L to 13.06 mg/L, with a mean value of 2.25 mg/L. The Mg concentration ranged from 3.42 mg/L to 72.21 mg/L, with an average value of 32.25 mg/L. Na values varied between 1.46-149.2 mg/L with a mean value of 84.4 mg/L in the pre-monsoon season. The concentration of HCO3- varied between 91-546 mg/L with a mean value of 309.5 mg/L

The mean concentration of heavy metals in the collected groundwater samples and their comparison with BIS limits is listed in Table 18. The concentration of arsenic (As) ranged from 0.005 ppm to 0.010 ppm with a mean value of 0.006 ppm. Mercury (Hg) was not detected in any groundwater sample in the current pre-monsoon 2023 season. Pb levels ranged from 0.001 to 0.008 ppm with an average of 0.002 ppm. The rest of the elements, such as Cd (BDL-0.001), Cr (0.006-0.015), Cu (0.029-0.116), Zn (0.07-1.002), Se (BDL-0.015), and, Fe (0.007-4.97) varied with average values of 0.001, 0.008, 0.04, 0.23, 0.003,

and 0.47 ppm, respectively. About 29% of the groundwater samples showed an elevated concentration of Fe in the present study area. This may be due to localized corrosion in the casing pipes of hand pumps. Moreover, natural geological processes may also be attributed to the release of iron into groundwater from iron-bearing minerals and rocks in the study area.

*Table 17. Mean concentration (in mg/L) of major ions in Groundwater samples and their comparison with BIS limits during pre-monsoon season of 2023*

| Sr. No. | Code | $F^-$ | $Cl^-$ | $Br^-$ | $NO_3^-$ | $PO_4^-$ | $SO_4^{2-}$ | Ca | K | Mg | Na | $CO_3^-$ | $HCO_3^-$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | KHR-1 | 0.3 | 71.1 | ND | 5.4 | ND | **803** | 185 | 1 | 47.3 | 36.1 | ND | 245 |
| 2 | KHR-2 | 0.5 | 85.1 | ND | 41.4 | ND | 57.6 | 133.5 | 13.1 | 24.3 | 125.0 | ND | 91 |
| 3 | KHR-3 | 0.6 | 72.6 | ND | 13.2 | ND | **414.1** | 142.8 | 0.5 | 37.5 | 86.2 | ND | 170 |
| 4 | KHR-4 | 0.5 | 50.1 | ND | 34.4 | ND | 219.8 | 111 | 0.7 | 28.6 | 34.8 | ND | 254 |
| 5 | KHR-5 | **3.3** | 48.8 | ND | 12.4 | ND | 98.9 | 17.4 | 0.9 | 3.4 | 135.7 | ND | 312 |
| 6 | KHR-6 | 0.5 | 72.7 | ND | **111.8** | ND | 131.8 | 164.8 | 7.7 | 54.2 | 88.7 | ND | 546 |
| 7 | KHR-7 | 0.4 | 42.3 | ND | **63.0** | ND | 68.3 | 168.8 | 1.4 | 35.7 | 41.8 | ND | 390 |
| 8 | KHR-8A | 0.5 | 18.6 | ND | 22.5 | ND | 19.6 | 69.2 | 0.3 | 17.6 | 74.4 | ND | 267 |
| 9 | KHR-9A | 0.4 | 71.7 | ND | **65.4** | ND | 53.5 | 70 | 0.9 | 36.5 | 91.5 | ND | 379 |
| 10 | KHR-10A | 0.5 | 38.9 | ND | 32.2 | ND | 67.6 | 98.7 | 0.7 | 6.3 | 123.5 | ND | 395 |
| 11 | KHR-11 | 0.6 | 24.3 | ND | **63.0** | ND | 60.8 | 76.8 | 3 | 27 | 1.5 | ND | 410 |
| 12 | KHR-12 | 0.7 | 16.4 | ND | **62.7** | ND | 48.6 | 13.6 | 1.1 | 41.2 | 45.5 | ND | 405 |
| 13 | KHR-13 | 0.5 | 30.6 | ND | 12.4 | ND | 135.8 | 209.2 | 1.3 | 20.2 | 131.8 | ND | 315 |
| 14 | KHR-14 | 0.9 | 62.3 | ND | **139.7** | ND | 47.2 | 115 | 0.7 | 35.3 | 39.9 | ND | 290 |
| 15 | KHR-15 | 0.6 | 58.7 | ND | **58.2** | ND | 284.7 | 189 | 0.8 | 17.1 | 120.3 | ND | 265 |
| 16 | KHR-17 | 0.6 | 100.4 | ND | 7.7 | ND | **429.5** | 212.5 | 2.2 | 40.7 | 104.0 | ND | 220 |
| 17 | KHR-18 | 0.6 | 39.7 | ND | 15.8 | ND | **921.1** | 192.6 | 0.3 | 72.2 | 67.8 | ND | 324 |
| 18 | KHR-19 | 0.5 | 78.6 | ND | 6.2 | ND | **787.3** | 75.4 | 3.1 | 14 | 149.2 | ND | 345 |
| 19 | KHR-20 | 0.4 | 43.6 | ND | **45.7** | ND | 117.9 | 195.8 | 0.6 | 32.5 | 68.9 | ND | 416 |
| 20 | KHR-25 | 0.3 | 43.9 | ND | **75.2** | ND | 56.6 | 225.6 | 5 | 55 | 134.1 | ND | 110 |
| 21 | KHRPz-1 | 0.4 | 125.4 | ND | 27.6 | ND | 116.7 | 241 | 1.6 | 35.4 | 60.8 | ND | 415 |
| 22 | KHRPz-2 | 0.3 | 72.5 | ND | 1.4 | ND | **996.8** | 202 | 0.9 | 29.7 | 80.0 | ND | 286 |
| 23 | KHRPz-3 | 0.3 | 68.0 | ND | 4.8 | ND | **983.7** | 190.1 | 1.1 | 11.2 | 126.1 | ND | 315 |
| 24 | KHRPz-4 | 0.8 | 86.3 | ND | ND | ND | **585.5** | 222 | 7.3 | 41 | 87.2 | ND | 264 |
| 25 | KHRPz-5 | 0.5 | 46.1 | ND | ND | ND | 187.2 | 235.7 | 1.8 | 24.7 | 101.2 | ND | 324 |
| 26 | KHRPz-6 | 0.4 | 86.1 | ND | 16.4 | ND | **436.2** | 183.4 | 0.6 | 49.8 | 38.5 | ND | 295 |
| **BIS limits (IS:10500-2012)** | **AL** | **1** | **250** | **NS** | **45** | **NS** | **200** | **75** | **NS** | **30** | **NS** | **NS** | **NS** |
| | **PL** | **1.5** | **1000** | | **NR** | | **400** | **200** | | **100** | | | |

*Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL- Permissible Limit; BDL: Below detection limit*

About 46% of groundwater samples show hard water quality. This might be due to the presence of excess Ca and Mg concentration in the groundwater samples. Only one sample collected from the village of Bhatyaan Khurd has the lowest pH value. This might be due to any mineral dissolution or leaching of surface water. Overall, the

groundwater quality in the pre-monsoon season is suitable for domestic use, indicating that it meets the standards and requirements necessary to provide safe and clean water for households.

*Table 18. Mean concentration (in ppm) of heavy metals in the groundwater samples and their comparison with BIS limits during pre-monsoon season of 2023*

| S.No. | Code | As | Hg | Pb | Cd | Cr | Cu | Zn | Se | Fe |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | KHR-1 | 0.008 | ND | 0.002 | 0.001 | 0.01 | 0.04 | 0.97 | ND | **0.39** |
| 2 | KHR-2 | 0.005 | ND | 0.002 | 0.001 | 0.01 | 0.04 | 0.98 | ND | **1.35** |
| 3 | KHR-3 | 0.007 | ND | 0.002 | 0.001 | 0.01 | 0.03 | 0.16 | ND | 0.08 |
| 4 | KHR-4 | 0.005 | ND | 0.002 | 0.001 | 0.01 | 0.03 | 0.07 | ND | 0.13 |
| 5 | KHR-5 | 0.010 | ND | 0.002 | BDL | 0.01 | 0.04 | 0.15 | ND | **0.52** |
| 6 | KHR-6 | 0.005 | ND | 0.002 | BDL | 0.01 | 0.05 | 0.13 | ND | **0.36** |
| 7 | KHR-7 | 0.006 | ND | 0.001 | 0.001 | 0.01 | 0.03 | 0.14 | ND | 0.27 |
| 8 | KHR-8A | 0.008 | ND | 0.002 | 0.001 | 0.01 | 0.04 | 0.21 | 0.01 | 0.23 |
| 9 | KHR-9A | 0.009 | ND | 0.002 | 0.001 | 0.01 | 0.04 | 0.15 | 0.01 | 0.13 |
| 10 | KHR-10A | 0.008 | ND | 0.002 | 0.001 | 0.01 | 0.04 | 0.23 | **0.02** | **0.38** |
| 11 | KHR -11 | 0.006 | ND | 0.002 | 0.001 | 0.01 | 0.04 | 0.08 | ND | 0.15 |
| 12 | KHR -12 | 0.006 | ND | 0.002 | BDL | 0.01 | 0.03 | 0.09 | ND | 0.18 |
| 13 | KHR -13 | 0.006 | ND | 0.002 | 0.001 | 0.01 | 0.04 | 0.13 | 0.01 | 0.09 |
| 14 | KHR -14 | 0.006 | ND | 0.002 | 0.001 | 0.01 | 0.07 | 0.48 | ND | 0.21 |
| 15 | KHR -15 | 0.005 | ND | 0.002 | 0.001 | 0.01 | 0.03 | 0.13 | 0.01 | 0.17 |
| 16 | KHR-17 | 0.006 | ND | 0.002 | BDL | 0.01 | 0.03 | 0.08 | ND | 0.17 |
| 17 | KHR-18 | 0.006 | ND | 0.002 | 0.001 | 0.01 | 0.03 | 0.07 | ND | 0.20 |
| 18 | KHR-19 | 0.006 | ND | 0.002 | 0.001 | 0.01 | 0.03 | 0.08 | ND | 0.12 |
| 19 | KHR-20 | 0.006 | ND | 0.002 | 0.001 | 0.01 | 0.03 | 0.11 | ND | 0.10 |
| 20 | KHR-25 | 0.007 | ND | 0.005 | 0.001 | 0.01 | 0.06 | 1.00 | ND | **4.97** |
| 21 | KHR PZ-1 | 0.006 | ND | 0.003 | 0.001 | 0.01 | 0.03 | 0.09 | ND | 0.13 |
| 22 | KHR PZ-2 | 0.006 | ND | 0.002 | 0.001 | 0.01 | 0.04 | 0.07 | ND | 0.13 |
| 23 | KHR PZ-3 | 0.006 | ND | 0.002 | 0.001 | 0.01 | 0.03 | 0.11 | ND | 0.17 |
| 24 | KHR PZ-4 | 0.007 | ND | 0.005 | 0.001 | 0.02 | 0.03 | 0.13 | ND | **0.33** |
| 25 | KHR PZ-5 | 0.007 | ND | 0.008 | 0.001 | 0.01 | 0.12 | 0.10 | ND | **0.98** |
| 26 | KHR PZ-6 | 0.006 | ND | 0.002 | 0.001 | 0.01 | 0.03 | 0.09 | ND | 0.20 |
| **BIS (IS:10500-2012)** | **AL** | **0.01** | **0.001** | **0.01** | **0.003** | **0.05** | **0.05** | **5** | **0.01** | **0.3** |
| | **PL** | **0.05** | **NR** | **NR** | **NR** | **NR** | **1.5** | **15** | **NR** | **NR** |

*Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL- Permissible Limit; BDL: Below detection limit*

## 7.2 *Groundwater Quality for Post-monsoon 2023 season*

The groundwater sampling for the post-monsoon season was undertaken during October 9 – 13, 2023. Salient details such as sample code, station name, location, and type of analysis for which groundwater samples were collected are given in Table 15.

*Table 19. Location of collected groundwater samples in the study area during the post-monsoon period for In-situ/Ex-situ analyses.*

| S.No. | Code | Latitude | Longitude | Station Name | Type of Analysis | Type of Site |
|---|---|---|---|---|---|---|
| 1 | KHR-1 | 22.07775 | 75.83155 | Vill. Dalchi | In-situ and Ex-situ | Hand pump |
| 2 | KHR-2 | 22.0609 | 75.7653 | Vill. Bhatyaan Khurd | In-situ and Ex-situ | Hand pump |
| 3 | KHR-3 | 22.06926 | 75.85789 | Near NTPC opp Bhilal Baba Temple, Gate No. 1 | In-situ and Ex-situ | Hand pump |
| 4 | KHR-4 | 22.0688 | 75.86202 | Between NTPC & Township | In-situ and Ex-situ | Hand pump |
| 5 | KHR-5 | 22.12494 | 75.8952 | Inside Primary School, Vill Baddgaon | In-situ and Ex-situ | Hand pump |
| 6 | KHR-6 | 22.12242 | 75.84251 | Opp. Madhya Pradesh Gramin Bank, Vill Kanapur | In-situ and Ex-situ | Hand pump |
| 7 | KHR-7 | 22.1235 | 75.794 | In House of sh. Daya Ram, Vill Londhi (Jhirbar) | In-situ and Ex-situ | Hand pump |
| 8 | KHR-8A | 22.10271 | 75.75548 | Karan Gangle Handpump, Pipalgone village. | In-situ and Ex-situ | Hand pump |
| 9 | KHR-9A | 22.10857 | 75.75845 | Lokesh Rathore Tubewell, Pipalgaon | In-situ and Ex-situ | Tube well |
| 10 | KHR-10A | 22.04086 | 75.81116 | Near Roop Singh house, Bhopada | In-situ and Ex-situ | Hand pump |
| 11 | KHR-11 | 22.00759 | 75.85122 | Near KHR 12, Hanuman Temple, Padaliya village | In-situ and Ex-situ | Hand pump |
| 12 | KHR-12 | 22.00728 | 75.85394 | Padaliya village | In-situ and Ex-situ | Hand pump |
| 13 | KHR-13 | 22.06608 | 75.87139 | Adjoining of NTPC Community Centre | In-situ and Ex-situ | Hand pump |
| 14 | KHR-14 | 22.0493 | 75.87783 | Opp Gram Panchayat office. Vill Kheri Bujurg | In-situ and Ex-situ | Hand pump |
| 15 | KHR-15 | 22.06923 | 75.85798 | Near Bhilal Baba Temple, Near NTPC Gate No. 1 | In-situ and Ex-situ | Hand pump |
| 16 | KHR-17 | 22.06947 | 75.85227 | Below Tower Line, North side of Power station, | In-situ and Ex-situ | Seepage |
| 17 | KHR-18 | 22.06295 | 75.85256 | Well inside power station | In-situ and Ex-situ | Open well |
| 18 | KHR-19 | 22.07518 | 75.82482 | Near Baba Ramdev Mandir, Dalchi | In-situ and Ex-situ | Hand pump |
| 19 | KHR-20 | 22.09205 | 75.84918 | Below Tower Line, North side of Power station, | In-situ and Ex-situ | Hand pump |
| 20 | KHR-25 | 22.02839 | 75.89527 | Rewa Gurjar Dharamshala, Umaria | In-situ and Ex-situ | Hand pump |
| 21 | KHR-Pz1 | 22.07826 | 75.8367 | Piezometer 1, Ash Dyke | In-situ and Ex-situ | Piezometer |
| 22 | KHR-Pz2 | 22.07721 | 75.83306 | Piezometer 1, Ash Dyke | In-situ and Ex-situ | Piezometer |
| 23 | KHR-Pz3 | 22.07476 | 75.83177 | Piezometer 1, Ash Dyke | In-situ and Ex-situ | Piezometer |
| 24 | KHR-Pz4 | 22.07289 | 75.83233 | Piezometer 1, Ash Dyke | In-situ and Ex-situ | Piezometer |
| 25 | KHR-Pz5 | 22.07055 | 75.83277 | Piezometer 1, Ash Dyke | In-situ and Ex-situ | Piezometer |
| 26 | KHR-Pz6 | 22.07089 | 75.83548 | Piezometer 1, Ash Dyke | In-situ and Ex-situ | Piezometer |

The mean value of in-situ parameters for the post-monsoon period is listed in *Table 16*. The DO concentrations ranged from 1.35 mg/L to 6.58 mg/L, with a mean value of 2.9 mg/L. TDS concentrations range from 225 mg/L to 1060 mg/L in the post-monsoon period, with an average value of 452.7 mg/L. The EC concentration ranged from 460 µs/cm to 2140 µs/cm, with an average value of 913.8 µs/cm. The pH value ranged between 6.85 -7.98, with an average value of 7.2 in the post-monsoon period. The temperature of groundwater in post-monsoon ranged from 27.7°C to 32.9°C with an average value of 30.3°C. The Hardness ranged from 29 mg/L to 870 mg/L in the pre-monsoon period, with an average of 390 mg/L.

*Table 20. Measured values of physical parameters (DO, TDS, EC, pH, Hardness and Temperature) in the groundwater samples during the post-monsoon period from In-situ analysis.*

| S.No. | Code | DO (mg/L) | TDS (mg/L) | EC (µS/cm) | pH | Temp (°C) | Hardness |
|---|---|---|---|---|---|---|---|
| 1 | KHR-1 | 2.9 | 590 | 1160 | 6.9 | 29.1 | 625 |
| 2 | KHR-2 | 1.9 | 470 | 950 | 7.1 | 29.3 | 549 |
| 3 | KHR-3 | 3.6 | 460 | 940 | 7.34 | 30.3 | 245 |
| 4 | KHR-4 | 6.58 | 490 | 1000 | 7.63 | 27.7 | 406 |
| 5 | KHR-5 | 1.9 | 280 | 570 | 7.98 | 29.4 | 29 |
| 6 | KHR-6 | 2.2 | 550 | 1130 | 7.1 | 28.4 | 457 |
| 7 | KHR-7 | 1.9 | 420 | 850 | 6.9 | 31.3 | 397 |
| 8 | KHR-8A | 2.7 | 225 | 460 | 7.1 | 30.4 | 120 |
| 9 | KHR-9A | 3.9 | 410 | 820 | 7.04 | 32.9 | 375 |
| 10 | KHR-10A | 1.7 | 275 | 550 | 7.3 | 30.2 | 234 |
| 11 | KHR-11 | 2.18 | 350 | 720 | 7.6 | 32.3 | 155 |
| 12 | KHR-12 | 2.96 | 360 | 750 | 7.02 | 30.1 | 330 |
| 13 | KHR-13 | 1.9 | 550 | 1100 | 7.24 | 30.7 | 620 |
| 14 | KHR-14 | 2.82 | 590 | 1190 | 6.9 | 32.1 | 435 |
| 15 | KHR-15 | 4.1 | 410 | 850 | 7.1 | 29.4 | 491 |
| 16 | KHR-17 | 4.97 | 470 | 960 | 7.3 | 29.3 | 297 |
| 17 | KHR-18 | 4.23 | 270 | 550 | 7.34 | 31.8 | 736 |
| 18 | KHR-19 | 2.3 | 540 | 1020 | 7.21 | 28.21 | 253 |
| 19 | KHR-20 | 3.1 | 430 | 870 | 6.9 | 32.1 | 365 |
| 20 | KHR-25 | 1.35 | 510 | 1020 | 7.18 | 30.9 | 331 |
| 21 | KHR-Pz1 | 3.6 | 400 | 810 | 7.52 | 29.1 | 332 |
| 22 | KHR-Pz2 | 2.3 | 1060 | 2140 | 7.08 | 29.2 | 793 |
| 23 | KHR-Pz3 | 26 | 270 | 550 | 7.42 | 29.9 | 230 |
| 24 | KHR-Pz4 | 1.6 | 770 | 1550 | 7.28 | 30.1 | 871 |
| 25 | KHR-Pz5 | 2.7 | 350 | 700 | 6.85 | 30.8 | 341 |
| 26 | KHR-Pz6 | 3.7 | 270 | 550 | 7.34 | 31.8 | 135 |
| **BIS Limits (IS:10500-2012)** | **AL** | **NS** | **500** | **NS** | **6.5-8.5** | **NS** | **200** |
| | **PL** | | **2000** | | **NR** | | **600** |

*Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL- Permissible Limit; BDL: Below detection limit*

Concentrations of major ions and other elements measured in groundwater samples and their comparison with BIS limits during the post-monsoon season are listed in *Table 17*. The concentration of $F^-$ ranged from BDL to 7.6 mg/L, with an average value of 0.9 mg/L. The concentration of $Cl^-$ ranged from 50 mg/L to 439.9 mg/L, with an average value of 147.8 mg/L. $NO_3^-$ levels ranged from BDL mg/L to 206 mg/L, with an average of 60.9 mg/L. $SO_4^{2-}$ levels ranged from BDL to 284.7 mg/L, with an average of 82.9 mg/L. In the post - monsoon season, the $Ca^{2+}$ concentration ranged from 8.4 mg/L to 215.8 mg/L, averaging

104.2 mg/L. Likewise, $K^+$ concentration ranged from 0.02 mg/L to 26.85 mg/L, with a mean value of 1.9 mg/L. The Mg concentration ranged from 1.95 mg/L to 80.55 mg/L, with an average value of 31.6 mg/L. Na values varied between 49.35-300.15 mg/L with a mean value of 141.4 mg/L in the post-monsoon season. The concentration of $HCO_3^-$ varied between 110-455 mg/L with a mean value of 286.2 mg/L

The mean concentration of heavy metals in the collected groundwater samples and their comparison with BIS limits 10500:2012 during the post-monsoon season of the year 2023 is listed in Table 18. The concentration of arsenic (As) ranged from BDL to 0.004 ppm with a mean value of 0.001 ppm. The concentration of Mercury (Hg) ranged from BDL to 0.012 ppm with a mean value of 0.001 ppm. Pb level ranged from BDL to 0.024 ppm with an average of 0.004 ppm. The rest of the elements, such as Cd (BDL-0.007), Cr (BDL-0.151), Cu (BDL-0.037), Zn (BDL- 0.707), Se (BDL-0.011), and, Fe (BDL-0.837) varied with average values of 0.002, 0.024, 0.008, 0.113, 0.001, and 0.255 ppm, respectively.

*Table 21. Mean concentration (in mg/L) of major ions in Groundwater samples and their comparison with BIS limits of IS 10500:2012 during post-monsoon season*

| Sr. No. | Code | $F^-$ | $Cl^-$ | $Br^-$ | $NO_3^-$ | $PO_4^-$ | $SO_4^{2-}$ | Ca | K | Mg | Na | $CO_3^-$ | $HCO_3^-$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | KHR-1 | 0.3 | 140 | ND | 20.5 | ND | 199.3 | 158 | 1.2 | 55.95 | 49.4 | ND | 210 |
| 2 | KHR-2 | 0.7 | 210 | ND | 62.1 | ND | 42.1 | 147 | 0.9 | 44.1 | 93.3 | ND | 110 |
| 3 | KHR-3 | 0.7 | 100 | ND | 22.6 | ND | 142 | 70.35 | 26.85 | 16.95 | 237.3 | ND | 165 |
| 4 | KHR-4 | BDL | 120 | ND | BDL | ND | BDL | 99.45 | 1.05 | 38.25 | 85.1 | ND | 250 |
| 5 | KHR-5 | **7.6** | 150 | ND | 10 | ND | 27 | 8.4 | 1.5 | 1.95 | 270.3 | ND | 295 |
| 6 | KHR-6 | 0.4 | 150 | ND | 86.5 | ND | 30.9 | 97.05 | 9.3 | 52.05 | 120.8 | ND | 455 |
| 7 | KHR-7 | 0.6 | 80 | ND | 79.3 | ND | 14.2 | 101.4 | 1.5 | 34.95 | 64.7 | ND | 350 |
| 8 | KHR-8A | 0.7 | 50 | ND | 16.5 | ND | 5.7 | 43.65 | 0.9 | 2.7 | 141.3 | ND | 265 |
| 9 | KHR-9A | 0.3 | 90 | ND | 135.4 | ND | 17 | 94.65 | 1.05 | 33.6 | 104.7 | ND | 310 |
| 10 | KHR-10A | 0.7 | 120 | ND | 94.4 | ND | 47.1 | 71.1 | 0.9 | 13.65 | 218.4 | ND | 410 |
| 11 | KHR-11 | 0.6 | 100 | ND | 48.4 | ND | 7.9 | 53.55 | 0.09 | 5.1 | 284.6 | ND | 390 |
| 12 | KHR-12 | 0.4 | 70 | ND | 118.9 | ND | 42.4 | 77.4 | 1.8 | 33.15 | 73.2 | ND | 375 |
| 13 | KHR-13 | 0.6 | 180 | ND | 187.5 | ND | 75.2 | 190.1 | 2.55 | 35.4 | 171 | ND | 290 |
| 14 | KHR-14 | 0.5 | 180 | ND | 200.6 | ND | 58.5 | 105.6 | 0.06 | 41.55 | 72.8 | ND | 275 |
| 15 | KHR-15 | 0.4 | 65 | ND | 45 | ND | 284.7 | 145 | 0.2 | 31.2 | 96.4 | ND | 245 |
| 16 | KHR-17 | 0.6 | 140 | ND | 26.5 | ND | 65.4 | 91.8 | 0.03 | 16.5 | 54.6 | ND | 245 |
| 17 | KHR-18 | **1.6** | 160 | ND | 54 | ND | 197.7 | 180.7 | 0.03 | 69.15 | 97.8 | ND | 310 |
| 18 | KHR-19 | 0.5 | 100 | ND | 14.6 | ND | 184.6 | 82.4 | 0.11 | 11.4 | 300.2 | ND | 290 |
| 19 | KHR-20 | 0.3 | 140 | ND | 101.8 | ND | 184.6 | 96.3 | 0.03 | 30.3 | 100.4 | ND | 390 |
| 20 | KHR-25 | 0.8 | 140 | ND | 100.2 | ND | 59 | 88.95 | 0.12 | 26.4 | 287 | ND | 150 |
| 21 | KHRPz-1 | 0.4 | 360 | ND | 25.7 | ND | 41.5 | 92.55 | 0.08 | 24.45 | 98.4 | ND | 310 |
| 22 | KHRPz-2 | 0.3 | 120 | ND | 12.2 | ND | 31.1 | 196.1 | 0.04 | 73.65 | 115.7 | ND | 310 |
| 23 | KHRPz-3 | 0.5 | 440 | ND | 16.1 | ND | 188 | 71.4 | 0.06 | 12.45 | 77.1 | ND | 290 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 24 | KHRPz-4 | **2.9** | 160 | ND | 15.4 | ND | 12.4 | 215.8 | 0.13 | 80.55 | 210.8 | ND | 245 |
| 25 | KHRPz-5 | 0.7 | 120 | ND | 72 | ND | 163.9 | 87.9 | 0.06 | 29.55 | 71.4 | ND | 265 |
| 26 | KHRPz-6 | 0.6 | 160 | ND | 16 | ND | 34 | 42.3 | 0.02 | 7.05 | 180.5 | ND | 240 |
| **BIS limits (IS:10500-2012)** | **AL** | **1** | **250** | **NS** | **45** | **NS** | **200** | **75** | **NS** | **30** | **NS** | **NS** | **NS** |
| | **PL** | **1.5** | **1000** | | **NR** | | **400** | **200** | | **100** | | | |

*Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL- Permissible Limit; BDL: Below detection limit*

*Table 22. Mean concentration (in ppm) of heavy metals in the groundwater samples and their comparison with BIS limits 10500:2012 during post-monsoon season*

| S.No. | Code | As | Hg | Pb | Cd | Cr | Cu | Zn | Se | Fe |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | KHR-1 | 0.002 | 0.004 | 0.003 | 0.003 | 0.02 | 0.005 | 0.46 | BDL | 0.18 |
| 2 | KHR-2 | 0.001 | 0.001 | 0.002 | 0.004 | 0.02 | 0.006 | 0.06 | 0.002 | 0.15 |
| 3 | KHR-3 | 0.001 | BDL | 0.003 | 0.002 | 0.02 | 0.010 | 0.71 | 0.002 | 0.43 |
| 4 | KHR-4 | 0.001 | BDL | 0.003 | 0.002 | 0.02 | 0.004 | 0.06 | BDL | 0.25 |
| 5 | KHR-5 | 0.004 | BDL | 0.003 | 0.002 | 0.02 | 0.003 | 0.02 | BDL | 0.45 |
| 6 | KHR-6 | 0.001 | 0.012 | BDL | 0.007 | 0.15 | 0.015 | BDL | 0.001 | 0.53 |
| 7 | KHR-7 | 0.001 | BDL | 0.005 | 0.002 | 0.02 | 0.013 | 0.02 | BDL | 0.26 |
| 8 | KHR-8A | 0.001 | BDL | 0.002 | 0.001 | 0.02 | 0.004 | 0.06 | 0.011 | 0.34 |
| 9 | KHR-9A | 0.001 | BDL | 0.004 | 0.002 | 0.02 | 0.009 | 0.01 | BDL | 0.20 |
| 10 | KHR-10A | 0.001 | BDL | 0.003 | 0.002 | 0.02 | 0.004 | 0.55 | 0.005 | 0.29 |
| 11 | KHR -11 | 0.001 | BDL | 0.003 | 0.002 | 0.02 | 0.005 | BDL | BDL | 0.17 |
| 12 | KHR -12 | 0.001 | BDL | 0.003 | 0.002 | 0.02 | 0.008 | 0.01 | BDL | 0.21 |
| 13 | KHR -13 | 0.002 | BDL | 0.003 | 0.002 | 0.02 | 0.007 | BDL | BDL | 0.19 |
| 14 | KHR -14 | 0.001 | BDL | 0.002 | 0.002 | 0.02 | 0.037 | 0.43 | BDL | 0.25 |
| 15 | KHR -15 | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL |
| 16 | KHR-17 | 0.001 | BDL | 0.002 | 0.002 | 0.02 | 0.002 | BDL | BDL | 0.21 |
| 17 | KHR-18 | 0.001 | BDL | 0.003 | 0.003 | 0.02 | 0.005 | BDL | BDL | 0.21 |
| 18 | KHR-19 | 0.001 | 0.002 | 0.002 | 0.002 | 0.02 | 0.005 | BDL | BDL | 0.20 |
| 19 | KHR-20 | 0.001 | BDL | 0.002 | 0.001 | 0.02 | 0.004 | 0.04 | BDL | 0.26 |
| 20 | KHR-25 | 0.001 | BDL | 0.003 | 0.002 | 0.02 | 0.007 | 0.45 | BDL | 0.84 |
| 21 | KHR PZ-1 | 0.001 | BDL | 0.024 | 0.002 | 0.02 | 0.011 | 0.05 | 0.001 | 0.18 |
| 22 | KHR PZ-2 | 0.001 | BDL | 0.002 | 0.001 | 0.02 | 0.004 | 0.01 | BDL | 0.16 |
| 23 | KHR PZ-3 | 0.001 | BDL | 0.010 | 0.002 | 0.02 | 0.009 | BDL | BDL | 0.15 |
| 24 | KHR PZ-4 | 0.001 | BDL | 0.009 | 0.001 | 0.02 | 0.005 | BDL | 0.002 | 0.23 |
| 25 | KHR PZ-5 | 0.001 | BDL | 0.003 | 0.001 | 0.02 | 0.014 | BDL | BDL | 0.16 |
| 26 | KHR PZ-6 | 0.001 | BDL | 0.008 | 0.001 | 0.02 | 0.007 | BDL | 0.009 | 0.14 |
| **BIS (IS:10500-2012)** | **AL** | **0.01** | **0.001** | **0.01** | **0.003** | **0.05** | **0.05** | **5** | **0.01** | **0.3** |
| | **PL** | **0.05** | **NR** | **NR** | **NR** | **NR** | **1.5** | **15** | **NR** | **NR** |

*Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL- Permissible Limit; BDL: Below detection limit*

## 8 ANALYSIS OF SOIL CHEMICAL PROPERTIES

Typically, the elements found in natural soil are represented by soil chemistry. However, many natural and anthropogenic processes alter the natural soil chemistry, including leaching of chemical elements by flood irrigation, chemical reactions, different patterns of land use, intense fertiliser usage, and biological processes. Depending on how the soil will be used in the future, these changes may be deemed to have either beneficial or adverse effects. In order to monitor the environment and determine potential effects on the local

ecology, it is crucial to examine the soil components close to thermal power stations. Various heavy metals (mercury, lead, cadmium, and arsenic), and other ions (nitrate) are among the many pollutants that thermal power stations frequently emit into the atmosphere. These emissions have the potential to pollute the soil when they settle onto it. These metals can build up in the soil over time and get into plants and animals, which then get into the food chain. Also, soil-borne pollutants have the potential to seep into groundwater and contaminate sources of drinking water. The possible migration of contaminants from the soil to groundwater can be better understood with the soil element analysis. Monitoring changes in soil quality over time is possible with routine soil element analyses. This ongoing observation provides the detailed characterisation which can be used to implement pollution control strategies. As per the scope of the present study, 36 soil samples were collected from 12 locations, and three samples from each location, i.e., from the surface, 30 cm and 60 cm depth from the surface were collected using an auger. The samples were appropriately tagged and placed in polythene bags for analysis in the laboratory. The samples were brought to IIT Roorkee Laboratory for further chemistry-based analysis.

### *8.1* ***Soil Chemical Properties during pre-monsoon 2023 season***

The geographical location of soil sampling locations in the study area is shown in Figure 14. Table 23 presents the details of the sampling locations. The results of laboratory analysis for physical parameters and major ions ($F^-$, $Cl^-$, $HCO_3^-$, $SO_4^{2-}$, $NO_3$, $PO_4^{3-}$, $Ca^{2+}$, $Mg^{2+}$, $Na^+$, $K^+$, and $Fe^{2+}$) are listed in Table 24.

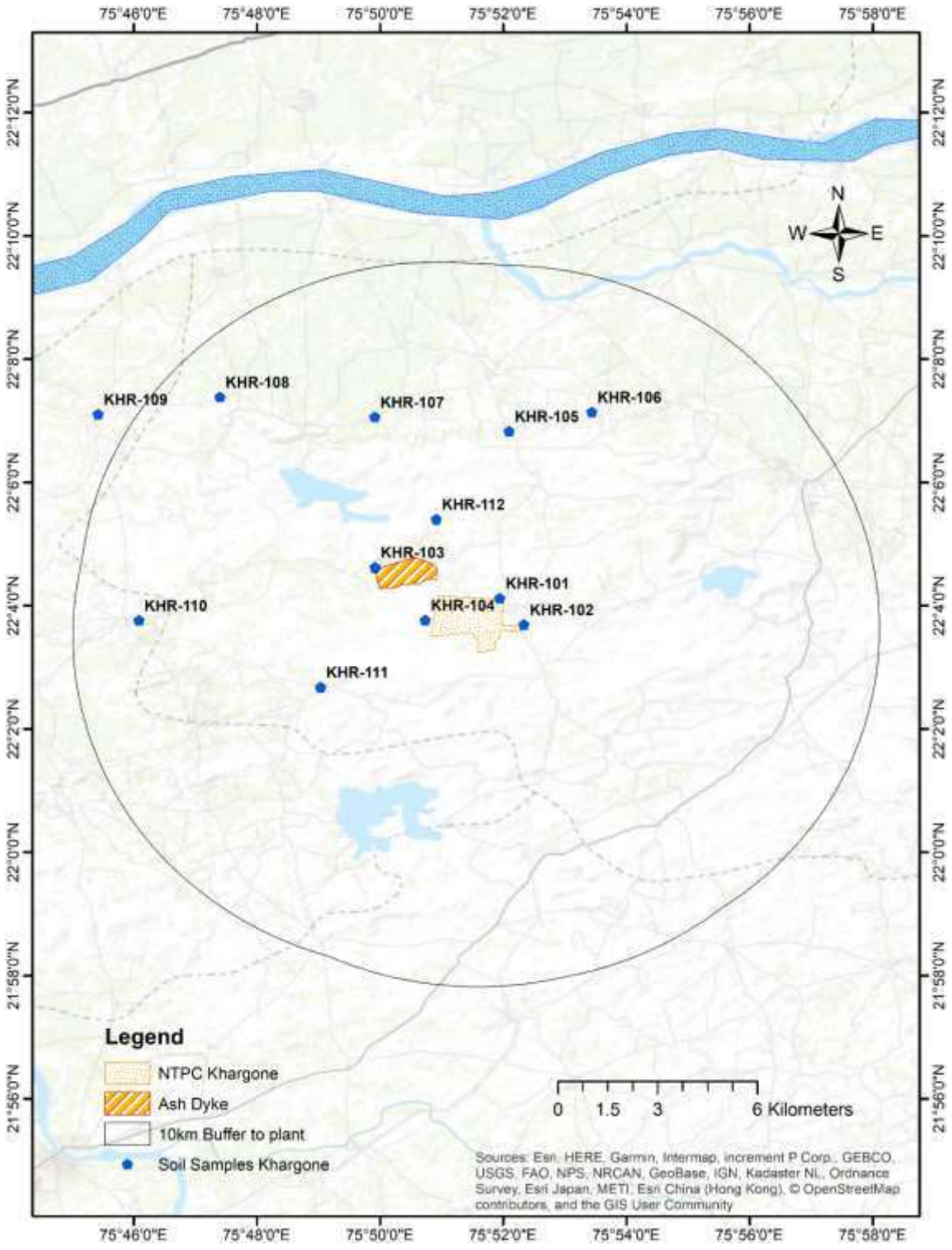


*Figure 14. Soil sampling points within the 10 km buffer zone of power station site in the study area*

*Table 23. Details of soils samples and their location name with geo-coordinates in the study area*

| S.No. | Site Code | Location name | Latitude | Longitude |
|---|---|---|---|---|
| 1 | KHR-101 | NTPC Plantation Land near Shelda Village | 22.068686 | 75.865808 |
| 2 | KHR-102 | NTPC Power station to Kheri road along NTPC Railway line | 22.061526 | 75.87233 |
| 3 | KHR-103 | Near NTPC Boundary inside Dalchi along Power station AshDyke - Dalchi road | 22.077065 | 75.832013 |
| 4 | KHR-104 | Power station to Bhopada side single Chimney side | 22.062734 | 75.845571 |
| 5 | KHR-105 | Opp side of Kottara Pond, Power station to Kattora Village | 22.113848 | 75.868283 |
| 6 | KHR-106 | Near Badgaon Village, Near Papu Dhaba | 22.119023 | 75.890667 |
| 7 | KHR-107 | Kanhapur- Pipalgaon Road ,Along Road site outside Kanhapur | 22.117732 | 75.83194 |
| 8 | KHR-108 | Pipalgaon Londi road, Londi along road side Near Hand Pump | 22.123119 | 75.790038 |
| 9 | KHR-109 | Opp Sant Siya ram Auto Parts & Garrage | 22.118459 | 75.757034 |
| 10 | KHR-110 | Village Bhatiyan On Power station road Near Overhead water tank opp side | 22.062688 | 75.768112 |
| 11 | KHR-111 | Village Bhopada Shalda Road | 22.044646 | 75.817312 |
| 12 | KHR-112 | Vill Jamnia | 22.090059 | 75.848602 |

The pH range for most soils varies between 3.5 and 10. The natural pH of soils normally ranges from 5 to 7 in areas with more rainfall and from 6.5 to 9 in dry regions. According to their pH value, soils can be categorized as neutral (pH range: 6.5 to 7.5), alkaline (pH over 7.5), or acidic (pH less than 6.5). Strongly acidic soils have a pH of less than 5.5. The pH range of the soil samples analysed in this study ranged from 6.05 to 7.5, with an average value of 6.8 when all sample depths were taken into account. The soil is frequently found to be neutral (34 out of 36 samples) within the pH range of 6.5 to 7.5. Only two samples showed acidic nature at 0 cm depth and 30 cm depth, respectively.

Soil electrical conductivity (EC), also known as the electrical conductivity of soil, is a measure of the soil's ability to conduct an electric current. It provides useful information about the physical and chemical qualities of the soil, as well as its moisture content and salinity. Soil EC monitoring is useful in a variety of sectors, including agriculture, environmental research, and geology. The value of EC for soil in the study area during the pre-monsoon period (April 2023) ranged from 150 µS/cm to 460 µS/cm with an average value of 262.9 µS/cm. Considering all the samples at various depths. Furthermore, no specific trend of depth-wise increase or decrease in EC values has been detected in the majority of soil samples. Moreover, the mean concentration of essential ions in soil samples at various depths (at surface, at 30 cm, and at 60 cm) during the pre-monsoon season of April (2023) is listed in Table 24.

*Table 24. Mean concentration of major ions in soil samples during pre-monsoon season of April (2023) (ions in mg/g, EC in µs/cm, pH in standard unit)*

| S.No. | Site Code | pH | EC | $CO_3^-$ | $HCO_3^-$ | $Cl^-$ | $SO_4^{2-}$ | $NO_3^-$ | $PO_4^-$ | $F^-$ | $Na^+$ | $K^+$ | $Ca^{2+}$ | $Mg^{2+}$ | $Br^-$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | KHR 101(0) | 6.9 | 230 | ND | 0.28 | 0.06 | 0.38 | 0.06 | ND | 0.001 | ND | 0.0004 | 0.02 | 0.006 | ND |
| 2 | KHR 101(30) | 6.7 | 240 | ND | 0.41 | 0.06 | 0.37 | 0.02 | ND | 0.001 | 0.015 | 0.0003 | 0.01 | 0.004 | ND |
| 3 | KHR 101(60) | 6.9 | 240 | ND | 0.36 | 0.05 | 0.22 | 0.02 | ND | 0.003 | 0.001 | 0.0012 | 0.02 | 0.007 | 0.001 |
| 4 | KHR 102 (0) | 6.8 | 170 | ND | 0.34 | 0.03 | 0.11 | 0.00 | ND | 0.005 | ND | 0.0009 | 0.02 | 0.007 | ND |
| 5 | KHR 102 (30) | 6.8 | 200 | ND | 0.49 | 0.02 | 0.16 | 0.01 | ND | 0.005 | ND | 0.0010 | 0.02 | 0.007 | ND |
| 6 | KHR 102(60) | 6.9 | 210 | ND | 0.34 | 0.02 | 0.15 | 0.02 | ND | 0.005 | ND | 0.0013 | 0.05 | 0.009 | 0.001 |
| 7 | KHR 103 (0) | 6.7 | 150 | ND | 0.66 | 0.03 | 0.22 | 0.04 | ND | 0.001 | 0.000 | 0.0009 | 0.01 | 0.004 | ND |
| 8 | KHR 103 (30) | 6.6 | 150 | ND | 0.73 | 0.03 | 0.25 | 0.03 | ND | 0.001 | 0.005 | 0.0009 | 0.01 | 0.004 | ND |
| 9 | KHR 103 (60) | 6.8 | 190 | ND | 0.92 | 0.04 | 0.25 | 0.04 | ND | 0.001 | ND | 0.0012 | 0.01 | 0.004 | ND |
| 10 | KHR 104(0) | 6.5 | 410 | ND | 0.31 | 0.05 | 0.28 | 0.21 | ND | 0.005 | ND | 0.0007 | 0.02 | 0.006 | 0.001 |
| 11 | KHR 104(30) | 6.8 | 280 | ND | 0.25 | 0.03 | 0.14 | 0.06 | ND | 0.005 | 0.006 | 0.0004 | 0.02 | 0.007 | 0.001 |
| 12 | KHR 104(60) | 6.9 | 260 | ND | 0.47 | 0.03 | 0.11 | 0.04 | ND | 0.007 | 0.001 | 0.0005 | 0.02 | 0.009 | 0.001 |
| 13 | KHR 105 (0) | 7.5 | 360 | ND | 0.14 | 0.07 | 0.30 | 0.28 | ND | 0.004 | 0.001 | 0.0004 | 0.02 | 0.005 | 0.003 |
| 14 | KHR 105 (30) | 7.3 | 230 | ND | 0.34 | 0.02 | 0.11 | 0.02 | ND | 0.004 | 0.001 | 0.0004 | 0.06 | 0.006 | 0.001 |
| 15 | KHR 105 (60) | 7.5 | 180 | ND | 0.37 | 0.02 | 0.14 | 0.01 | ND | 0.005 | 0.001 | 0.0002 | 0.07 | 0.006 | ND |
| 16 | KHR 106 (0) | 6.1 | 360 | ND | 0.50 | 0.06 | 0.15 | 0.44 | 0.02 | 0.002 | 0.001 | 0.0006 | 0.02 | 0.010 | ND |
| 17 | KHR 106 (30) | 6.6 | 220 | ND | 0.26 | 0.06 | 0.08 | 0.05 | ND | 0.004 | ND | 0.0005 | 0.01 | 0.009 | ND |
| 18 | KHR 106 (60) | 6.5 | 190 | ND | 0.30 | 0.11 | 0.07 | 0.14 | 0.11 | 0.005 | ND | 0.0004 | 0.02 | 0.009 | ND |
| 19 | KHR 107 (0) | 6.9 | 350 | ND | 0.67 | 0.02 | 0.04 | 0.16 | 0.01 | ND | 0.004 | 0.0007 | 0.02 | 0.006 | ND |
| 20 | KHR 107 (30) | 6.8 | 310 | ND | 0.45 | 0.03 | 0.06 | 0.10 | ND | ND | 0.001 | 0.0006 | 0.04 | 0.006 | ND |
| 21 | KHR 107 (60) | 6.8 | 305 | ND | 0.51 | 0.02 | 0.09 | 0.13 | 0.01 | ND | 0.038 | 0.0003 | 0.04 | 0.008 | ND |
| 22 | KHR 108(0) | 6.4 | 310 | ND | 0.70 | 0.15 | 0.09 | 0.01 | ND | ND | 0.001 | 0.0005 | 0.02 | 0.006 | ND |
| 23 | KHR 108(30) | 6.3 | 190 | ND | 0.37 | 0.13 | 0.04 | 0.08 | 0.01 | ND | 0.006 | 0.0003 | 0.01 | 0.004 | ND |
| 24 | KHR 108(60) | 6.7 | 210 | ND | 0.40 | 0.14 | 0.12 | 0.08 | ND | ND | 0.002 | 0.0006 | 0.04 | 0.005 | ND |
| 25 | KHR 109 (0) | 6.5 | 330 | ND | 0.59 | 0.10 | 0.16 | 0.09 | 0.01 | 0.004 | ND | 0.0012 | 0.03 | 0.008 | 0.001 |
| 26 | KHR 109 (30) | 6.9 | 360 | ND | 0.73 | 0.09 | 0.20 | 0.03 | 0.01 | 0.005 | 0.001 | 0.0022 | 0.04 | 0.012 | 0.001 |
| 27 | KHR 109 (60) | 7.2 | 320 | ND | 0.51 | 0.10 | 0.11 | 0.09 | 0.01 | 0.008 | 0.001 | 0.0012 | 0.03 | 0.007 | 0.001 |
| 28 | KHR 110 (0) | 6.6 | 460 | ND | 0.47 | 0.12 | 0.33 | 0.21 | ND | 0.003 | 0.005 | 0.0030 | 0.02 | 0.005 | ND |
| 29 | KHR 110 (30) | 6.6 | 300 | ND | 0.23 | 0.05 | 0.13 | 0.08 | ND | 0.002 | ND | 0.0038 | 0.02 | 0.007 | ND |
| 30 | KHR 110 (60) | 6.6 | 230 | ND | 0.30 | 0.04 | 0.12 | 0.05 | ND | 0.004 | 0.001 | 0.0025 | 0.02 | 0.006 | ND |
| 31 | KHR 111 (0) | 6.8 | 210 | ND | 0.58 | 0.07 | 0.16 | 0.03 | ND | 0.003 | 0.001 | 0.0029 | 0.02 | 0.009 | ND |
| 32 | KHR 111 (30) | 6.8 | 150 | ND | 0.30 | 0.07 | 0.16 | 0.01 | ND | 0.004 | 0.003 | 0.0018 | 0.04 | 0.011 | ND |
| 33 | KHR 111 (60) | 6.7 | 200 | ND | 0.35 | 0.06 | 0.13 | 0.04 | ND | 0.004 | 0.002 | 0.0039 | 0.03 | 0.015 | ND |
| 34 | KHR112 (0) | 6.9 | 340 | ND | 0.63 | 0.15 | 0.01 | 0.09 | ND | ND | ND | 0.0009 | 0.01 | 0.006 | ND |
| 35 | KHR112 (30) | 6.8 | 310 | ND | 0.14 | 0.10 | 0.07 | 0.01 | 0.01 | 0.009 | 0.002 | 0.0008 | 0.03 | 0.008 | ND |
| 36 | KHR112 (60) | 6.9 | 310 | ND | 0.63 | 0.19 | 0.08 | 0.08 | ND | ND | 0.003 | 0.0008 | 0.03 | 0.007 | ND |

*Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL- Permissible Limit; BDL: Below detection limit*

Heavy metals (HMs) are naturally occurring minerals found in soil; however, human activities can contribute considerably to high amounts of these metals in the soil. Moreover, heavy metals can enter the soil through the use of certain fertilizers, insecticides, and animal dung. Also, they are released into the soil by the degradation of rocks and minerals

in the Earth's crust. However, the presence of these metals is influenced by soil composition, local geology, and geological processes. Heavy metal pollution in the soil can harm ecosystems, human health, and agricultural output. Therefore, various HMs have been analyzed in the soil samples collected from the power station area. The mean concentration of heavy metals in the soil samples at various depths during the pre-monsoon season of April (2023) is listed in Table 25.

*Table 25. Mean concentration of heavy metals in the soil samples during pre-monsoon season of April (2023)*

| Sr. No. | Site Code | Cr (mg/g) | Fe (mg/g) | Cu (mg/g) | Zn (mg/g) | As (mg/g) | Se (mg/g) | Cd (mg/g) | Hg (mg/g) | Pb (mg/g) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | KHR 101 (0) | 0.002 | 2.7 | 0.007 | 0.005 | ND | ND | ND | ND | ND |
| 2 | KHR 101 (30) | 0.001 | 1.6 | 0.004 | 0.003 | ND | ND | ND | ND | ND |
| 3 | KHR 101 (60) | 0.002 | 3.1 | 0.008 | 0.004 | ND | ND | ND | ND | ND |
| 4 | KHR 102 (0) | 0.003 | 2.5 | 0.008 | 0.005 | ND | ND | ND | ND | ND |
| 5 | KHR 102 (30) | 0.003 | 2.4 | 0.008 | 0.006 | ND | ND | ND | ND | ND |
| 6 | KHR 102 (60) | 0.003 | 2.4 | 0.008 | 0.004 | ND | ND | ND | ND | ND |
| 7 | KHR 103 (0) | 0.002 | 3.6 | 0.011 | 0.006 | ND | ND | ND | ND | ND |
| 8 | KHR 103 (30) | 0.002 | 3.7 | 0.011 | 0.006 | ND | ND | ND | ND | ND |
| 9 | KHR 103 (60) | 0.002 | 3.9 | 0.012 | 0.005 | ND | ND | ND | ND | ND |
| 10 | KHR 104 (0) | 0.002 | 2.1 | 0.006 | 0.005 | ND | ND | ND | ND | ND |
| 11 | KHR 104 (30) | 0.002 | 2.2 | 0.006 | 0.005 | ND | ND | ND | ND | ND |
| 12 | KHR 104 (60) | 0.002 | 2.6 | 0.007 | 0.004 | ND | ND | ND | ND | ND |
| 13 | KHR 105 (0) | 0.001 | 1.2 | 0.002 | 0.003 | ND | ND | ND | ND | ND |
| 14 | KHR 105 (30) | 0.001 | 1.4 | 0.002 | 0.003 | ND | ND | ND | ND | ND |
| 15 | KHR 105 (60) | 0.001 | 1.2 | 0.002 | 0.002 | ND | ND | ND | ND | ND |
| 16 | KHR 106 (0) | 0.001 | 2.0 | 0.003 | 0.005 | ND | ND | ND | ND | ND |
| 17 | KHR 106 (30) | 0.001 | 2.5 | 0.003 | 0.003 | ND | ND | ND | ND | ND |
| 18 | KHR 106 (60) | 0.001 | 2.4 | 0.005 | 0.002 | ND | ND | ND | ND | ND |
| 19 | KHR 107 (0) | 0.002 | 1.5 | 0.003 | 0.003 | ND | ND | ND | ND | ND |
| 20 | KHR 107 (30) | 0.002 | 1.4 | 0.003 | 0.006 | ND | ND | ND | ND | ND |
| 21 | KHR 107 (60) | 0.001 | 1.5 | 0.003 | 0.003 | ND | ND | ND | ND | ND |
| 22 | KHR 108 (0) | 0.002 | 2.0 | 0.005 | 0.004 | ND | ND | ND | ND | ND |
| 23 | KHR 108 (30) | 0.001 | 1.6 | 0.004 | 0.003 | ND | ND | ND | ND | ND |
| 24 | KHR 108 (60) | 0.001 | 1.5 | 0.005 | 0.005 | ND | ND | ND | ND | ND |
| 25 | KHR 109 (0) | 0.002 | 2.2 | 0.006 | 0.003 | ND | ND | ND | ND | ND |
| 26 | KHR 109 (30) | 0.003 | 3.0 | 0.008 | 0.005 | ND | ND | ND | ND | ND |
| 27 | KHR 109 (60) | 0.002 | 1.8 | 0.005 | 0.003 | ND | ND | ND | ND | ND |
| 28 | KHR 110 (0) | 0.001 | 1.5 | 0.005 | 0.003 | ND | ND | ND | ND | ND |
| 29 | KHR 110 (30) | 0.001 | 2.2 | 0.008 | 0.005 | ND | ND | ND | ND | ND |
| 30 | KHR 110 (60) | 0.001 | 1.9 | 0.006 | 0.004 | ND | ND | ND | ND | ND |
| 31 | KHR 111 (0) | 0.002 | 3.9 | 0.012 | 0.007 | ND | ND | ND | ND | ND |
| 32 | KHR 111 (30) | 0.006 | 5.5 | 0.016 | 0.010 | ND | ND | ND | ND | ND |
| 33 | KHR 111 (60) | 0.003 | 5.9 | 0.020 | 0.010 | ND | ND | ND | ND | ND |
| 34 | KHR 112 (0) | 0.001 | 1.8 | 0.008 | 0.002 | ND | ND | ND | ND | ND |
| 35 | KHR 112 (30) | 0.004 | 4.0 | 0.012 | 0.009 | ND | ND | ND | ND | ND |
| 36 | KHR 112 (60) | 0.003 | 2.8 | 0.014 | 0.006 | ND | ND | ND | ND | ND |

*Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL- Permissible Limit; BDL: Below detection limit.*

## *8.2 Soil Chemical Properties during post-monsoon 2023 season*

The results of laboratory analysis for physico-chemical parameters and major ions ($F^-$, $Cl^-$, $HCO_3^-$, $SO_4^{2-}$, $NO_3$, $PO_4^{3-}$, $Ca^{2+}$, $Mg^{2+}$, $Na^+$, $K^+$, and $Fe^{2+}$) are listed in Table 24. The pH range of the soil samples analyzed in the post monsoon study ranged from 6.08 to 7.5, with an average value of 6.88 when all sample depths were considered. The nature of the soil does not shown variation during post monsoon period as compared to pre monsoon season. The value of EC for soil in the study area during the post-monsoon period ranged from 180 µS/cm to 390 µS/cm with an average value of 262.22 µS/cm. Considering all the samples at various depths. Furthermore, no specific trend of depth-wise increase or decrease in EC values has been detected in the majority of soil samples similarly to pre-monsoon period. The mean concentration of heavy metals in the soil samples at various depths during the post-monsoon season of year 2023 is listed in Table 25.

*Table 26. Mean concentration of major ions in soil samples during post-monsoon season of 2023 (ions in mg/g, EC in µs/cm, pH in standard unit)*

| S.No. | Site Code | pH | EC | $CO_3^-$ | $HCO_3^-$ | $Cl^-$ | $SO_4^{2-}$ | $NO_3^-$ | $PO_4^-$ | $F^-$ | $Na^+$ | $K^+$ | $Ca^{2+}$ | $Mg^{2+}$ | $Br^-$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | KHR 101(0) | 6.75 | 280 | ND | 0.26 | 0.10 | 0.31 | 0.06 | ND | 0.01 | 0.0010 | 0.0002 | 0.002 | 0.0004 | ND |
| 2 | KHR 101(30) | 6.43 | 180 | ND | 0.39 | 0.10 | 0.29 | 0.12 | ND | BDL | 0.0003 | 0.0001 | 0.001 | 0.0001 | ND |
| 3 | KHR 101(60) | 6.24 | 270 | ND | 0.33 | 0.08 | 0.16 | 0.11 | ND | BDL | 0.0010 | 0.0001 | 0.002 | 0.0005 | ND |
| 4 | KHR 102 (0) | 6.35 | 180 | ND | 0.28 | 0.10 | 0.19 | 0.08 | ND | 0.01 | 0.0009 | 0.0002 | 0.001 | 0.0003 | ND |
| 5 | KHR 102 (30) | 6.50 | 270 | ND | 0.45 | 0.08 | 0.11 | 0.07 | ND | 0.01 | 0.0009 | 0.0002 | 0.002 | 0.0004 | ND |
| 6 | KHR 102(60) | 6.55 | 240 | ND | 0.32 | 0.10 | 0.17 | 0.10 | ND | 0.01 | 0.0010 | 0.0002 | 0.002 | 0.0004 | ND |
| 7 | KHR 103 (0) | 6.57 | 280 | ND | 0.59 | 0.04 | 0.24 | 0.10 | ND | BDL | 0.0011 | 0.0002 | 0.002 | 0.0005 | ND |
| 8 | KHR 103 (30) | 6.67 | 260 | ND | 0.66 | 0.16 | 0.26 | 0.17 | ND | BDL | 0.0011 | 0.0002 | 0.002 | 0.0005 | ND |
| 9 | KHR 103 (60) | 6.68 | 270 | ND | 0.46 | 0.10 | 0.24 | 0.08 | ND | BDL | 0.0011 | 0.0002 | 0.002 | 0.0005 | ND |
| 10 | KHR 104(0) | 6.64 | 330 | ND | 0.28 | 0.18 | 0.18 | 0.50 | ND | 0.01 | 0.0008 | 0.0003 | 0.003 | 0.0005 | ND |
| 11 | KHR 104(30) | 6.08 | 290 | ND | 0.29 | 0.18 | 0.14 | 0.15 | ND | 0.01 | 0.0012 | 0.0003 | 0.002 | 0.0006 | ND |
| 12 | KHR 104(60) | 7.07 | 250 | ND | 0.34 | 0.08 | 0.17 | 0.02 | ND | 0.01 | 0.0014 | 0.0001 | 0.001 | 0.0004 | ND |
| 13 | KHR 105 (0) | 6.92 | 390 | ND | 0.24 | 0.20 | 0.18 | 0.04 | ND | BDL | 0.0008 | 0.0002 | 0.003 | 0.0004 | ND |
| 14 | KHR 105 (30) | 7.06 | 180 | ND | 0.29 | 0.14 | 0.19 | 0.07 | ND | BDL | 0.0006 | 0.0001 | 0.001 | 0.0002 | ND |
| 15 | KHR 105 (60) | 7.00 | 240 | ND | 0.32 | 0.16 | 0.18 | 0.08 | ND | 0.01 | 0.0008 | 0.0002 | 0.002 | 0.0003 | ND |
| 16 | KHR 106 (0) | 6.90 | 300 | ND | 0.49 | 0.12 | 0.05 | 1.43 | ND | BDL | 0.0008 | 0.0002 | 0.002 | 0.0005 | ND |
| 17 | KHR 106 (30) | 7.50 | 180 | ND | 0.28 | 0.14 | 0.04 | 0.15 | ND | BDL | 0.0008 | 0.0001 | 0.001 | 0.0003 | ND |
| 18 | KHR 106 (60) | 7.03 | 190 | ND | 0.62 | 0.12 | 0.05 | 0.09 | ND | BDL | 0.0008 | 0.0001 | 0.001 | 0.0003 | ND |
| 19 | KHR 107 (0) | 6.92 | 360 | ND | 0.46 | 0.26 | 0.06 | 0.11 | ND | BDL | 0.0013 | 0.0002 | 0.003 | 0.0008 | ND |
| 20 | KHR 107 (30) | 7.05 | 280 | ND | 0.29 | 0.14 | 0.40 | 0.10 | ND | BDL | 0.0014 | 0.0002 | 0.002 | 0.0007 | ND |
| 21 | KHR 107 (60) | 7.08 | 250 | ND | 0.41 | 0.16 | 0.07 | 0.12 | ND | BDL | 0.0011 | 0.0001 | 0.002 | 0.0005 | ND |
| 22 | KHR 108(0) | 7.07 | 300 | ND | 0.49 | 0.24 | 0.06 | 0.10 | ND | BDL | 0.0012 | 0.0003 | 0.002 | 0.0006 | ND |
| 23 | KHR 108(30) | 7.27 | 260 | ND | 0.65 | 0.16 | 0.05 | 0.02 | ND | BDL | 0.0014 | 0.0001 | 0.002 | 0.0005 | ND |
| 24 | KHR 108(60) | 7.24 | 220 | ND | 0.37 | 0.12 | 0.08 | 0.19 | ND | BDL | 0.0011 | 0.0001 | 0.002 | 0.0004 | ND |
| 25 | KHR 109 (0) | 7.19 | 240 | ND | 0.39 | 0.24 | 0.11 | 0.14 | ND | 0.01 | 0.0018 | 0.0002 | 0.002 | 0.0004 | ND |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 26 | KHR 109 (30) | 7.12 | 290 | ND | 0.46 | 0.12 | 0.15 | 0.10 | ND | 0.01 | 0.0024 | 0.0002 | 0.002 | 0.0005 | ND |
| 27 | KHR 109 (60) | 7.22 | 270 | ND | 0.49 | 0.12 | 0.14 | 0.10 | ND | 0.01 | 0.0031 | 0.0001 | 0.001 | 0.0003 | ND |
| 28 | KHR 110 (0) | 6.96 | 350 | ND | 0.26 | 0.26 | 0.18 | 0.41 | ND | BDL | 0.0008 | 0.0008 | 0.003 | 0.0006 | ND |
| 29 | KHR 110 (30) | 7.04 | 250 | ND | 0.64 | 0.22 | 0.19 | 0.04 | ND | 0.01 | 0.0010 | 0.0005 | 0.002 | 0.0005 | ND |
| 30 | KHR 110 (60) | 7.08 | 230 | ND | 0.87 | 0.16 | 0.17 | 0.12 | ND | BDL | 0.0008 | 0.0003 | 0.002 | 0.0005 | ND |
| 31 | KHR 111 (0) | 7.12 | 240 | ND | 0.49 | 0.16 | 0.22 | 0.12 | ND | BDL | 0.0011 | 0.0002 | 0.002 | 0.0006 | ND |
| 32 | KHR 111 (30) | 7.16 | 220 | ND | 0.29 | 0.10 | 0.29 | 0.02 | ND | BDL | 0.0010 | 0.0001 | 0.001 | 0.0004 | ND |
| 33 | KHR 111 (60) | 7.16 | 250 | ND | 0.27 | 0.16 | 0.24 | 0.04 | ND | BDL | 0.0011 | 0.0001 | 0.002 | 0.0006 | ND |
| 34 | KHR112 (0) | 6.70 | 290 | ND | 0.62 | 0.10 | 0.17 | 0.70 | ND | BDL | 0.0012 | 0.0002 | 0.002 | 0.0006 | ND |
| 35 | KHR112 (30) | 6.70 | 260 | ND | 0.36 | 0.14 | 0.20 | 0.08 | ND | BDL | 0.0011 | 0.0001 | 0.002 | 0.0005 | ND |
| 36 | KHR112 (60) | 6.80 | 300 | ND | 0.58 | 0.12 | 0.19 | 0.07 | ND | BDL | 0.0011 | 0.0001 | 0.002 | 0.0006 | ND |

*Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL- Permissible Limit; BDL: Below detection limit*

*Table 27. Mean concentration of heavy metals in the soil samples during post-monsoon season of year 2023*

| Sr. No. | Site Code | Cr (mg/g) | Fe (mg/g) | Cu (mg/g) | Zn (mg/g) | As (mg/g) | Se (mg/g) | Cd (mg/g) | Hg (mg/g) | Pb (mg/g) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | KHR 101 (0) | 0.003 | 0.007 | 0.003 | 0.001 | ND | ND | ND | ND | ND |
| 2 | KHR 101 (30) | 0.002 | 0.009 | 0.001 | ND | ND | ND | ND | ND | ND |
| 3 | KHR 101 (60) | 0.003 | 0.012 | 0.003 | ND | ND | ND | ND | ND | ND |
| 4 | KHR 102 (0) | 0.003 | 0.009 | 0.003 | 0.001 | ND | ND | ND | ND | ND |
| 5 | KHR 102 (30) | 0.003 | 0.010 | 0.003 | ND | ND | ND | ND | ND | ND |
| 6 | KHR 102 (60) | 0.003 | 0.010 | 0.003 | ND | ND | ND | ND | ND | ND |
| 7 | KHR 103 (0) | 0.005 | 0.014 | 0.004 | 0.001 | ND | ND | ND | ND | ND |
| 8 | KHR 103 (30) | 0.003 | 0.009 | 0.003 | 0.001 | ND | ND | ND | ND | ND |
| 9 | KHR 103 (60) | 0.002 | 0.008 | 0.003 | ND | ND | ND | ND | ND | ND |
| 10 | KHR 104 (0) | 0.003 | 0.011 | 0.005 | 0.001 | ND | ND | ND | ND | ND |
| 11 | KHR 104 (30) | 0.004 | 0.011 | 0.003 | 0.001 | ND | ND | ND | ND | ND |
| 12 | KHR 104 (60) | 0.005 | 0.012 | 0.003 | 0.001 | ND | ND | ND | ND | ND |
| 13 | KHR 105 (0) | 0.003 | 0.010 | 0.002 | 0.001 | ND | ND | ND | ND | ND |
| 14 | KHR 105 (30) | 0.003 | 0.009 | 0.001 | ND | ND | ND | ND | ND | ND |
| 15 | KHR 105 (60) | 0.003 | 0.008 | 0.002 | 0.002 | ND | ND | ND | ND | ND |
| 16 | KHR 106 (0) | 0.003 | 0.010 | 0.002 | 0.001 | ND | ND | ND | ND | ND |
| 17 | KHR 106 (30) | 0.005 | 0.011 | 0.002 | ND | ND | ND | ND | ND | ND |
| 18 | KHR 106 (60) | 0.003 | 0.007 | 0.002 | ND | ND | ND | ND | ND | ND |
| 19 | KHR 107 (0) | 0.003 | 0.010 | 0.004 | 0.002 | ND | ND | ND | ND | ND |
| 20 | KHR 107 (30) | 0.003 | 0.012 | 0.003 | 0.003 | ND | ND | ND | ND | ND |
| 21 | KHR 107 (60) | 0.004 | 0.011 | 0.002 | 0.003 | ND | ND | ND | ND | ND |
| 22 | KHR 108 (0) | 0.006 | 0.008 | 0.004 | 0.002 | ND | ND | ND | ND | ND |
| 23 | KHR 108 (30) | 0.003 | 0.009 | 0.003 | 0.002 | ND | ND | ND | ND | ND |
| 24 | KHR 108 (60) | 0.003 | 0.010 | 0.002 | 0.002 | ND | ND | ND | ND | ND |
| 25 | KHR 109 (0) | 0.003 | 0.010 | 0.003 | 0.001 | ND | ND | ND | ND | ND |
| 26 | KHR 109 (30) | 0.003 | 0.011 | 0.003 | 0.002 | ND | ND | ND | ND | ND |
| 27 | KHR 109 (60) | 0.003 | 0.010 | 0.002 | 0.002 | ND | ND | ND | ND | ND |
| 28 | KHR 110 (0) | 0.003 | 0.010 | 0.005 | 0.002 | ND | ND | ND | ND | ND |
| 29 | KHR 110 (30) | 0.004 | 0.014 | 0.005 | 0.003 | ND | ND | ND | ND | ND |
| 30 | KHR 110 (60) | 0.003 | 0.009 | 0.003 | 0.002 | ND | ND | ND | ND | ND |
| 31 | KHR 111 (0) | 0.002 | 0.009 | 0.003 | 0.002 | ND | ND | ND | ND | ND |
| 32 | KHR 111 (30) | 0.003 | 0.007 | 0.002 | 0.002 | ND | ND | ND | ND | ND |
| 33 | KHR 111 (60) | 0.002 | 0.007 | 0.003 | 0.002 | ND | ND | ND | ND | ND |
| 34 | KHR 112 (0) | 0.003 | 0.013 | 0.003 | 0.004 | ND | ND | ND | ND | ND |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **35** | KHR 112 (30) | 0.003 | 0.008 | 0.002 | 0.002 | ND | ND | ND | ND | ND |
| **36** | KHR 112 (60) | 0.003 | 0.007 | 0.002 | 0.002 | ND | ND | ND | ND | ND |

*Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL- Permissible Limit; BDL: Below detection limit.*

# 9 ISOTOPE DATA ANALYSIS

Isotopes can play a significant role in studying the origin, age, occurrence, and distribution of groundwater in a region, recharge mechanism, determination of groundwater flow direction and velocity; interconnections and interaction between aquifers; and identification of recharge areas and sources. Isotopes can also be applied to study surface water and groundwater interaction etc.

In the present study, groundwater and surface water samples were collected from different sources such as hand pumps, tube wells, and open wells for isotopic characterisation of the waters of study area. Water samples were collected from different sources for analysis of stable isotopes. For the analysis of $\delta^{2}H$, $\delta^{18}O$, a 20 ml sample was collected in pre-cleaned Polypropylene bottles (Tarsons make). The bottles were rinsed and filled with water samples and tightly capped (to prevent evaporation and exchange with air). On-site measurements like sample temperature, pH, and conductivity, along with all other relevant site information, were also recorded.

The stable isotope ratio is the molar ratio of heavy to light isotopes and is known as the abundance ratio. It is denoted by $\delta(x)$ and given by

$$\delta(x) = \{\frac{R_{SAMPLE}}{R_{STANDARD}} - 1\} * 1000 \text{ (in permil / ‰)}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \ldots\ldots\ldots(1)$$

where δ(x) is the delta value of the sample for element' x' in permil (‰), and R is the molar ratio of the heavy-to-light isotope in the sample. Different isotope standards can determine the isotopic compositions, the most common being VSMOW (Vienna Standard Mean Ocean Water). Water isotope ratios vary with the season, and groundwater isotope values differ from GMWL and LMWL due to (i) natural intermittent processes such as evaporation, infiltration, and percolation and (ii) anthropogenic-driven processes. A small fraction of rain percolates through the soil to become

groundwater; however, significant modifications in signatures are observed in meteoric water, particularly in arid and semi-arid regions.

## *9.1 Isotope Analysis for Pre-monsoon 2023*

For the study, 16 representative groundwater samples were collected from semi-arid regions in the Khargone district of Madhya Pradesh during the pre-monsoon season. Six groundwater samples were collected from the piezometer, seven from the handpump, two from the tube well, and one from the open well. The ratios of heavy stable isotopes were measured using Dual Inlet Isotope Ratio Mass Spectrometer-DI IRMS. The results of $\delta^{18}O$ varied from -0.69 to -4.84 ‰ with an average value of -2.61 ‰, whereas $\delta^{2}H$ varied from -9.11 to - 37.07 ‰ with an average value of -19.43 ‰. The characteristic isotope lines of groundwater samples are very closely related to the LMWL (as shown in Table 28), indicating that meteoric water is the primary source of recharge in groundwater. The slight variation in the slope of GMWL (8) and LMWL (7.68) may be due to differences in the source of moisture and climatic and geographic conditions. The overall slope of the groundwater sample (5.74) is less steep than the LMWL (7.68), indicating the occurrence of evaporation before water infiltration in the vadose zone. The individual trends of piezometer samples (06), handpump (07), tube wells (02), and the open well (01) are showing the similar patterns. Figure 15 represents isotopic characterization for groundwater samples based on plots between $\delta^{2}H$ and $\delta^{18}O$.

*Table 28 Characteristic isotope lines of GMWL, LMWL, and groundwater samples for Pre-monsoon 2023*

| S. No. | Component type | Regression equation |
|---|---|---|
| 1 | Global meteoric water line (Craig, 1961) | $\delta^{2}H = \mathbf{8}\ \delta^{18}O + 10$ |
| 2 | Local meteoric water line (Deshpande et al., 2013) | $\delta^{2}H = \mathbf{7.68}\ \delta^{18}O + 5.77$ |
| 3 | Groundwater representative samples | $\delta^{2}H = \mathbf{5.74}\ \delta^{18}O - 4.54$ |

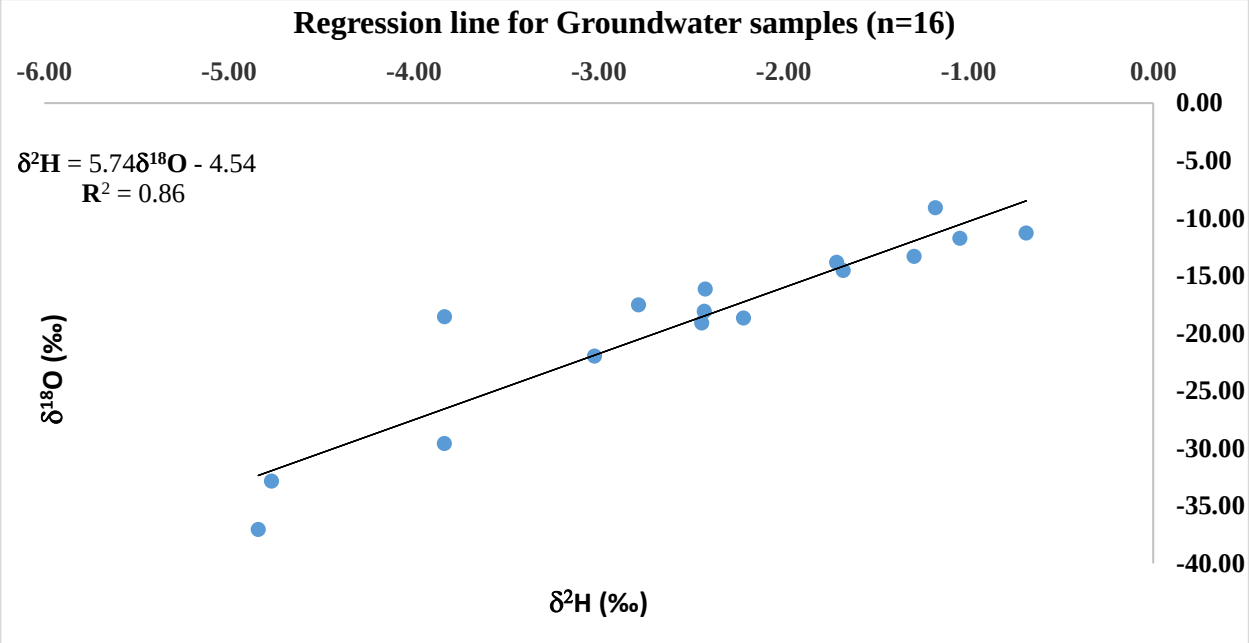


*Figure 15. Isotopic characterization for Groundwater samples collected from piezometers (06), handpump (07), tube-wells (02), and the open well (01) for Pre-monsoon 2023.*

## 9.2 *Isotope Analysis for Post-monsoon 2023*

The $\delta^{18}O$ varied from -0.64 to -9.02 ‰ with an average value of -3.62 ‰, whereas $\delta^{2}H$ varied from -9.04 to – 48.71 ‰ with an average value of -21.93 ‰. The characteristic isotope lines of groundwater samples are very closely related to the LMWL (as shown in Table 28). The overall slope of the post- monsoon groundwater samples (5.09) is less steep than the LMWL (7.68) and pre- monsoon groundwater samples (5.74), indicating meteoric water to be primary source of groundwater recharge. The individual trends of piezometer samples (06), handpump (07), tubewells (02), and the open well (01) are showing the similar patterns as in case of pre-monsoon season. The variation in intercept due to differences in the source of moisture and climatic conditions. The contribution from each factor cannot be equal and it can be negligible in some places. Some rapid changes are likely linked to poor well integrity and anulus flow, highlighting the risk to groundwater sources from surface water intrusion.

Moreover, the suggested predominance of evaporation in both pre and post season due to semi-arid conditions is also observed.

Figure 16 shows Isotopic characterization for Groundwater samples collected from piezometers (06), handpump (07), tube-wells (02), and the open well (01) in the post-monsoon season.

*Table 29 Characteristic isotope lines of GMWL, LMWL, and groundwater samples for Post-monsoon 2023*

| S. No. | Component type | Regression equation |
|---|---|---|
| 1 | Global meteoric water line (Craig, 1961) | $\delta^2H$ = **8** $\delta^{18}O$ + 10 |
| 2 | Local meteoric water line (Deshpande et al., 2013) | $\delta^2H$ = **7.68** $\delta^{18}O$ + 5.77 |
| 3 | Groundwater representative samples | $\delta^2H$ = **5.09** $\delta^{18}O$ - 0.05 |

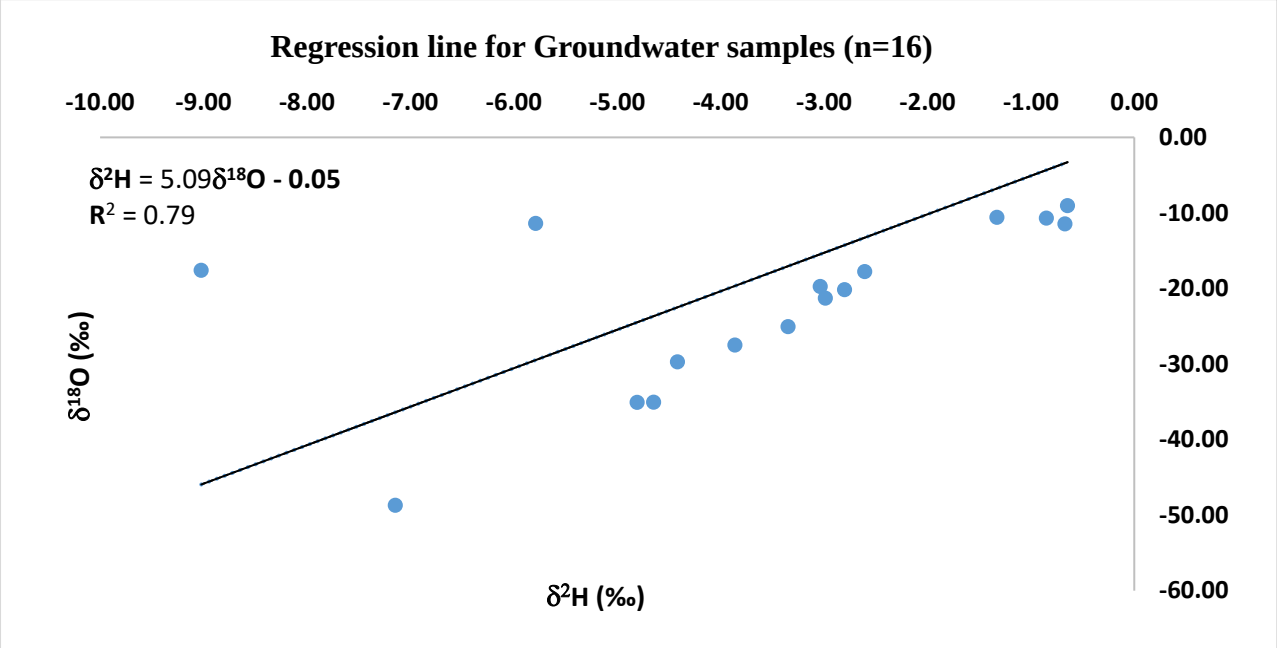


*Figure 16. Isotopic characterization for Groundwater samples collected from piezometers (06), handpump (07), tube-wells (02), and the open well (01) for Post-monsoon 2023.*

# 10 SUMMARY AND CONCLUSION

Site visits to NTPC Khargone power station, located near villages Selda, Balabad and Dalchi in Barwah tehsil of Khargone district of Madhya Pradesh, and the surrounding 10 km area were undertaken for pre-monsoon season during April 25 – 30, 2023, and for post-monsoon season during October 9 – 13, 2023 by the survey team of IIT Roorkee. During these site visits, groundwater and surface water samples were collected from different sources such as hand pumps, tube wells, open wells, ponds, reservoirs, rivers, ash dyke and piezometers etc. Groundwater table depth was also measured in existing open wells and piezometers for the preparation of groundwater table and flow direction maps. Soil samples at the surface, 30 cm, and 60 cm from the ground were also collected and brought to IIT Roorkee for the analysis of soil chemical properties, like EC, pH, major ions (Na, K, Ca, Mg, Fe, $CO_3$, $HCO_3$, Cl, $SO_4$, $NO_3$, F-, and $PO_4$), and Heavy metals (Cd, Zn, Hg, As, Cr, Pb etc.). Collected surface and groundwater samples were analysed to measure water quality parameters like pH, EC, DO, BOD, COD, major cations (Na, K, Ca, Mg, and Fe etc.), major anions (CO3, HCO3, Cl, SO4, NO3, F-, and PO4 etc.) and Heavy metals (Cd, Zn, Hg, As, Cr, Pb etc.). Some water quality parameters were determined using in-situ probes, and major cations, anions and heavy metals were determined using laboratory facilities available at IIT Roorkee. The following conclusions are made based on the analysis of 1$^{st}$ year of sampling (pre and post-monsoon 2023 data).

1. Analysis of groundwater table observation reveals that, in general, the groundwater is flowing in two distinct patterns. The groundwater in the area to the north of the power station flows northwards towards Narmada River, and the groundwater in the area to the southern side of the power station flows towards south and southwest direction.
2. The groundwater table contour map of the area is found mostly in line with its surface drainage pattern.
3. The water quality of most of the surface water samples was found to be well within the prescribed limits of BIS standards during the pre-monsoon 2023 season. The concentration of a few elements such as fluoride, sulphate and

some heavy metals such as Fe, Se, and As was found to be slightly higher than the prescribed BIS limits of drinking water in ash dyke samples. Also, the pH values were slightly high in surface water samples collected from the ash dyke area.

4. The water quality of most of the groundwater samples was found to be well within the prescribed limits of BIS standards during the pre-monsoon 2023 season. The concentration of a few elements such as fluoride, nitrate, sulphate, and some heavy metals such as Fe, and Se was found to be slightly higher than the prescribed BIS limits of drinking water in a few groundwater samples during pre-monsoon 2023 season, which will be ascertained further during upcoming post-monsoon visit. Overall, the groundwater quality in the pre-monsoon season is suitable for domestic use, indicating that it meets the standards and requirements necessary to provide safe and clean water for households.
5. The pH range of the soil samples analyzed in this study ranged from 6.05 to 7.5, with an average value of 6.8 when all sample depths were considered. The soil is frequently found to be neutral (34 out of 36 samples) within the pH range of 6.5 to 7.5. Only two samples showed acidic nature at 0 cm depth and 30 cm depth, respectively. Other soil chemical properties were found well within the prescribed limits.
6. The overall slope of the post- monsoon groundwater samples (5.09) is less steep than the LMWL (7.68) and pre- monsoon groundwater samples (5.74), indicating meteoric water to be primary source of groundwater recharge. The individual trends of piezometer samples (06), handpump (07), tubewells (02), and the open well (01) are showing the similar patterns as in case both pre-monsoon season and post-monsoon season.

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## Appendix-A: Photographs of Sampling Sites

| Sl. No. | Site Details | Location Details | Location Photograph |
|---|---|---|---|
| **Ground Water Sites** | | | |
| 1. | Site Code: KHR1<br>Latitude: 22.077748<br>Longitude: 75.831549 | In House of Sh. Rai Singh S/O Sh. Jai Sing. On Road of Pipalgaon to NTPC Power station, Near Electric Triangle pole of HT Line, Vill Dalchi |  |
| 2. | Site Code: KHR2<br>Lat: 22.060904<br>Long: 75.765297 | Anganwadi & School Compound Near Hanuman Mandir, Vill Bhatyaan Khurd<br>Remarks: Nearby well depth was also taken |  |
| 3. | Site Code: KHR3<br>Lat: 22.069258<br>Long: 75.857885 | Near NTPC opp Bhilal Baba Temple, Gate No. 1,opp Cooling Towers, Below Bargad Tree |  |

| | | | |
|---|---|---|---|
| 4. | Site Code: KHR4<br>Lat: 22.068803<br>Long: 75.862023 | Between NTPC & Town ship, opposite to Boundary Pillar S.N. 230-240 |  |
| 5. | Ste Code: KHR5<br>Lat: 22.124938<br>Long: 75.895198 | Inside Primary School, Vill Baddgaon<br>Remarks: Nearby well depth also measured |  |
| 6. | Site Code: KHR5A<br>Lat: 22.12407<br>Long: 75.89518 | Adjacent to main road, Vill Badgaon |  |

| | | | |
|---|---|---|---|
| 7. | Site Code: KHR6<br>Lat: 22.122422<br>Long: 75.842507 | opp Madhya Pradesh Gramin Bank, opp Health Centre. Vill Kanapur<br>Remarks: Indiamarka Handpump |  |
| 8. | Site Code: KHR6A<br>Lat: 22.12545<br>Long: 75.84165 | Well in the field, Vill Kanapur |  |
| 9. | Site Code: KHR7<br>Lat: 22.123495<br>Long: 75.794 | In House of sh. Daya Ram, Vill Londhi (Jhirbar) |  |

| | | | |
|---|---|---|---|
| 10. | Site Code: KHR7A<br>Lat: 22.12314<br>Long: 75.7963 | Londhi village<br>Remarks: Motor was running at time of measurement |  |
| 11. | Site Code: KHR7B<br>Lat: 22.12126<br>Long: 75.79317 | Londhi village |  |
| 12. | Site Code: KHR8A<br>Lat: 22.10271<br>Long: 75.75548 | Karan Gangle Handpump, Pipalgone village.<br>Remarks: Nearby well depth also measured |  |

| | | | |
|---|---|---|---|
| 13. | Site Code: KHR9A<br>Lat: 22.10857<br>Long: 75.75845 | Lokesh Rathore Tubewell, Pipalgaon |  |
| 14. | Site Code: KHR10<br>Lat: 22.04166<br>Long: 75.81254 | Near Anganwadi Kendra, Bhopada |  |
| 15. | Site Code: KHR10A<br>Lat: 22.04086<br>Long: 75.81116 | Near Roop Singh house, Bhopada<br>Remarks: Indiamarka handpump |  |

| | | | |
|---|---|---|---|
| 16. | Site Code: KHR11<br>Lat: 22.007591<br>Long: 75.851219 | Near KHR 12, Hanuman Temple, Padaliya village |  |
| 17. | Site Code: KHR12<br>Lat: 22.007275<br>Long:75.853942 | Padaliya village<br>Remarks: Gawali samaj Dharamshala |  |
| 18. | Site Code: KHR13<br>Lat: 22.066083<br>Long: 75.871388 | Adjoining of NTPC Community Centre Near New Hanumaan Temple<br>Remarks: Measurement of nearby well also done |  |

| | | | |
|---|---|---|---|
| 19. | Site Code: KHR14<br>Lat: 22.049303<br>Long: 75.877826 | Opp Gram Panchayat office. Vill Kheri Bujurg |  |
| 20. | Site Code: KHR15<br>Lat: 22.069233<br>Long: 75.857978 | Near Bhilal Baba Temple, opposite cooling tower, Near NTPC Gate No. 1 |  |
| 21. | Site Code: KHR15A<br>Lat: 22.07092<br>Long: 75.85599 | Near KHR 15 and KHR 3, Below Mango tree |  |

| | | | |
|---|---|---|---|
| 22. | Site Code: KHR16A<br>Lat: 22.07912<br>Long: 75.80412 | Adjacent to Gangour thermal power station road |  |
| 23. | Site Code: KHR17<br>Lat: 22.069467<br>Long: 75.852274 | Below Tower Line, North side of Power station, Side of NTPC Road<br>Remarks: Seepage water from below power station |  |
| 24. | Site Code: KHR18<br>Lat: 22.062953<br>Long: 75.852559 | Well inside power station |  |

| | | | |
|---|---|---|---|
| 25. | Site Code: KHR19<br>Lat: 22.075184<br>Long: 75.824819 | opp Community Centre Near Primary School, Near Baba Ramdev Mandir, Dalchi |  |
| 26. | Site Code: KHR20<br>Lat: 22.092052<br>Long: 75.849177 | Below Tower Line, North side of Power station, Side of NTPC Road |  |
| 27. | Site Code: KHR20A<br>Lat: 22.0833<br>Long:75.8515 | Maal Singh Jhapdiya Well, Jamniya village |  |

| | | | |
|---|---|---|---|
| 28. | Site Code: KHR21<br>Lat: 22.12321<br>Long:75.90812 | Adjacent to pipalgone road |  |
| 29. | Site Code: KHR22<br>Lat: 22.11305<br>Long: 75.92877 | Adjacent to Pipalgone road |  |
| 30. | Site Code: KHR23<br>Lat: 22.10902<br>Long: 75.93549 | Adjacent to Pipalgone road |  |

| | | | |
|---|---|---|---|
| 31. | Site Code: KHR24<br>Lat: 22.04485<br>Long: 75.87855 | Adjacent to Umaria road |  |
| 32. | Site Code: KHR25<br>Lat: 22.02839<br>Long: 75.89527 | In front of Rewa Gurjar Dharamshala, Gram panchayat office, Umaria<br>Remarks: Nearby handpump measurement was also done |  |
| 33. | Site Code: KHR26<br>Lat: 21.99242<br>Long: 75.86363 | In the field adjacent to Padaliya road |  |

| **Surface Water Sites** | | | |
|---|---|---|---|
| 34. | Site Code: KHR51<br>Lat: 22.07047<br>Long: 75.858149 | Pond Between NTPC Power station & Township |  |
| 35. | Site Code: KHR52<br>Lat: 22.12206<br>Long: 75.842803 | Pond near Health Centre at Main Road, Vill Kanapur |  |
| 36. | Site Code: KHR53<br>Lat: 22.104185<br>Long: 75.812277 | Jirbhar lake |  |

| | | | |
|---|---|---|---|
| 37. | Site Code: KHR54A<br>Lat: 22.158804<br>Long: 75.76167 | Narmada River Downstream |  |
| 38. | Site Code: KHR55<br>Lat: 22.006354<br>Long: 75.848828 | Ambak Reservoir |  |
| 39. | Site Code: KHR56<br>Lat: 22.075493<br>Long: 75.927687 | Lachhora Talab |  |

| | | | |
|---|---|---|---|
| 40. | Site Code: KHR57<br>Lat: 22.115246<br>Long: 75.866087 | Kattora Pond, Shelda Power station-Kattora Road |  |
| 41. | Site Code: KHR58<br>Lat: 22.07323<br>Long: 75.833941 | OFL Ash Dyke |  |
| 42. | Site Code: KHR59<br>Lat: 22.073978<br>Long: 75.839568 | Lagoon 1 Ash Dyke<br>Remarks: Dried up |  |

| | | | |
|---|---|---|---|
| 43. | Site Code: KHR60<br>Lat: 22.07661<br>Long: 75.8332 | Lagoon 2 Ash Dyke |  |
| 44. | Site Code: KHR61<br>Lat: 22.06741<br>Long: 75.860638 | Raw water reservoir inside power station | Photo not taken |
| 45. | Site Code: KHR61A<br>Lat: 22.063462<br>Long: 75.855098 | Aerated water from raw water reservoir |  |
| 46. | Site Code: KHR62<br>Lat: 22.07441<br>Long: 75.850902 | Nala flowing as groundwater drainage below tower line on road crossing near power station. |  |

| | | | |
|---|---|---|---|
| 47. | Site Code: KHR63<br>Lat: 22.1927<br>Long: 75.97763 | Narmada River upstream, Toksar |  |
| 48. | Site Code: KHR64<br>Lat: 22.00772<br>Long: 75.90917 | Ambak River, Khargone-Sanawad road |  |

| **Soil Sampling Sites** | | | |
|---|---|---|---|
| 49. | Site Code: KHR101<br>Lat: 22.068686<br>Long: 75.865808 | NTPC Plantation Land near Shelda Village |  |
| 50. | Site Code: KHR102<br>Lat: 22.061526<br>Long: 75.87233 | NTPC Power station to Kheri road along NTPC Railway line |  |
| 51. | Site Code: KHR103<br>Lat: 22.077065<br>Long: 75.832013 | Near NTPC Boundary inside Dalchi along Power station AshDyke - Dalchi road |  |

| | | | |
|---|---|---|---|
| 52. | Site Code: KHR104<br>Lat: 22.062734<br>Long: 75.845571 | Power station to Bhopada side single Chimney side |  |
| 53. | Site Code: KHR105<br>Lat: 22.113848<br>Long: 75.868283 | opp side of Kottara Pond, Power station to Kattora Village |  |
| 54. | Site Code: KHR106<br>Lat: 22.119023<br>Long: 75.890667 | Near Badgaon Village, Near Papu Dhaba |  |

| | | | |
|---|---|---|---|
| 55. | Site Code: KHR107<br>Lat: 22.117732<br>Long: 75.83194 | Kanhapur-Pipalgaon Road ,Along Road site outside Kanhapur |  |
| 56. | Site Code: KHR108<br>Lat: 22.123119<br>Long: 75.790038 | Pipalgaon Londi road, Londi along road side Near Hand Pump |  |
| 57. | Site Code: KHR109<br>Lat: 22.118459<br>Long: 75.757034 | opp Sant Siya ram Auto Parts & Garrage |  |

| | | | |
|---|---|---|---|
| 58. | Site Code: KHR110<br>Lat: 22.062688<br>Long: 75.768112 | Village Bhatiyan On Power station road Near Overhead water tank opp side |  |
| 59. | Site Code: KHR111<br>Lat: 22.044646<br>Long: 75.817312 | Village Bhopada Shalda Road |  |
| 60. | Site Code: KHR112<br>Lat: 22.090059<br>Long: 75.848602 | Vill Jamnia |  |

| **Piezometers around ash dyke** | | | |
|---|---|---|---|
| 61. | Site Code: KHR PZ1<br>Lat: 22.07826<br>Long: 75.8367 | Piezometer 1, Ash Dyke |  |
| 62. | Site Code: KHR PZ2<br>Lat: 22.07721<br>Long: 75.83306 | Piezometer 2, Ash Dyke |  |
| 63. | Site Code: KHR PZ3<br>Lat: 22.07476<br>Long: 75.83177 | Piezometer 3, Ash Dyke |  |

| | | | |
|---|---|---|---|
| 64. | Site Code: KHR PZ4<br>Lat: 22.07289<br>Long: 75.83233 | Piezometer 4, Ash Dyke |  |
| 65. | Site Code: KHR PZ5<br>Lat: 22.07055<br>Long: 75.83277 | Piezometer 5, Ash Dyke |  |
| 66. | Site Code: KHR PZ6<br>Lat: 22.07089<br>Long: 75.83548 | Piezometer 6, Ash Dyke |  |

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TC-11703

# Radioanalytical Laboratory

## RADIOACTIVITY TEST CERTIFICATE

**Ref : BRIT/RAL/DOM/1479-1490/MISC/1130-1141/23-24**

**To :**
**M/S NTPC LIMITED**
**KHARGONE SUPER THERMAL POWER PROJECT**
**PO: SELDA, SO : BEDIYA,**
**DISTT : KHARGONE - 451 114,**
**MADHYA PRADESH**

This is regarding the sample of "COAL, DRY FLY ASH & BOTTOM ASH" sent for radioactivity analysis vide your letter ref. no. NTPC/KGN/EMG/BRIT/2023 dated 09.03.2024 as shown in italics:

| Sr. No | SAMPLE DESCRIPTION | SAMPLE LOCATION | SAMPLING DATE |
|---|---|---|---|
| 1 | COAL (DRY POWDER) | FEEDER MIX UNIT# 1 & 2 | 13.02.24 |
| 2 | FLY ASH (DRY POWDER) | FA SILO | 15.02.24 |
| 3 | BOTTOM ASH (DRY POWDER) | BA LAGOON 3 | 15.02.24 |

**DATE OF RECEIPT OF SAMPLE: 09.03.2024** **DATE OF COMPLETION OF TEST: 08.05.2024**

The samples were analysed for U-238, Ra-226 , Th-232 and K-40 radioactivity content by HPGe gamma spectrometry and the values obtained are as follows:

| Sr. No | NAME OF THE PRODUCT | U-238 (Bq/Kg) | Ra-226 (Bq/Kg) | Th-232 (Bq/Kg) | K-40 (Bq/Kg) |
|---|---|---|---|---|---|
| 1 | COAL (DRY POWDER) | 8 ± 0.7 | 14.2 ± 1.9 | 6.5 ± 0.6 | MDL ± 6.1 |
| 2 | FLY ASH (DRY POWDER) | 79.3 ± 3.0 | 74.3 ± 6.2 | 102-.8 ± 11.0 | 220.5 ± 16.5 |
| 3 | BOTTOM ASH (DRY POWDER) | 66.5 ± 2.5 | 72.2 ± 6.3 | 105.6 ± 12.6 | 165 ± 12.8 |

Opinion: The measurement values are below the clearance level for radionuclides of natural origin in bulk solid materials, as per AERB directive 01/2010 (table-3) dated 26/11/2010.

Note: (i) The report pertains to the given sample only. (ii) The sample will be retained in this laboratory for a period of 1 month from certificate date and thereafter it will be disposed off. (iii) This report shall not be reproduced except in full, without written approval of the laboratory. (iv) The sampling is not done by this laboratory.

**Checked by:**
GANPAT B NAKTI
Assistant

**Authorized Signatory:**
N. JAYACHANDRAN
Scientific Officer/G

********** End of Report **********

## Annexure-4

# Community Development Works by NTPC-Khargone STPS

## FY: 2023-24 (October 2023 to March 2024)

**Inauguration of Nurufaliya Primary school Construed by NTPC Khargone.**

**Organization of Girl Empowerment mission Follow-up Workshop at 11 Project Affected Villages in which more than 35 girls were benefitted.**

**Organization of Mega Health checkup camp at Dalchi Village**

**Skill Development classes: Basic Computer coaching to 25 children from 03 PAVs**

**MOU Inked between NTPC Khargone and NM Sadhguru Foundation for support for Domestic Water security at Sirvel Mahadev cluster.**

**Education- Stationery and School Bag Distribution to PAV Govt. Schools**

**Organization of District Level Athletics at NTPC Khargone Stadium in which more than 500 students participated.**

**Organization of Dalchi Cricket Cup for rural youth at Dalchi Ground**

**Construction of Nurufailya-Jamniya and Lallyachapad Internal Road**

ANNEXURE-5

एनटीपीसी NTPC

एन टी पी सी लिमिटेड
(भारत सरकार का उद्यम)
NTPC Limited
(A Govt. of India Enterprise)

Ref: KGN/EMG/MOEF/Ann. Return/ACR 2023-24

Date: 29.04.2024

To
**Additional Principal Chief Conservator of Forests (C),**
**Ministry of Environment, Forest, and Climate Change,**
Regional Office (WZ), Kendriya Paryavaran Bhawan,
E-5 Arera Colony, Link Road-3, Ravishankar Nagar,
Bhopal-462016, Madhya Pradesh
Email id- rowz.bpl-mef@nic.in
moefcc-coalash@gov.in

**Sub: Submission of Annual Compliance Report for Ash Utilization for FY 2023-24**

**Ref:** MOEF&CC, Notification S.O.-5481(E), dated 31.12.2021: Annual Compliance Report

Dear Sir,

With respect to the above-mentioned subject & reference, we are submitting **Annual Compliance Report** (ACR) of Ash Utilization in prescribed performa as **Annexure-1,** in soft copy vide email for the period **01.04.2023 to 31.03.20234** at NTPC-Khargone STPS.

Submitted for your kind information and perusal please.

Thanking you,

Yours Sincerely,

**(Ashish Kumar Agarwal)**
**AGM (Ash & Environment Management)**

**Enclosure:**
1. Annexure-1: ACR of AU for FY 2023-24

**Copy to (Email) :-**
1. Member Secretory, CPCB, Delhi (mscb.cpcb@nic.in)
2. Member Secretory, MPPCB, Bhopal (ms-mppcb@mp.gov.in)
3. Regional Officer, MPPCB, Indore (ropcb-indore@mp.gov.in)

# Ash Compliance Report

## (for the period 1st April'2023 to 31st March'2024)

(to be submitted on or before 31st May)

**Ref.-MoEFCC Notification S.O. 5481(E), Dated-31.12.2021**

| S. No. | Details | Status |
|---|---|---|
| 1 | **Name of Power Plant** | **Khargone Super Thermal Power Project** |
| 2 | **Name of the company** | **NTPC Ltd.** |
| 3 | **District** | Khargone |
| 4 | **State** | Madhya Pradesh |
| 5 | **Postal address for communication:** | Village-Selda, PO-SPO NTPC-Selda, |
| 6 | **E-mail:** | emgkhargone@ntpc.co.in |
| 7 | **Power Plant installed capacity (MW):** | **1320** |
| 8 | **Plant Load Factor (PLF %):** | **66.29** |
| 9 | **No. of units generated (MWh):** | **768643** |
| 10 | **Total area under power plant (ha): (including area under ash ponds)** | **554.42** |
| 11 | **Quantity of coal consumption during reporting period MTPA (Metric Tons Per Annum):** | **4702128** |
| 12 | **Average ash content in percentage (percent):** | **37.55** |
| 13 | **Quantity of current ash generation during reporting period MTPA (Metric Tons Per Annum):** | **1765426** |
| | **Fly ash MTPA (Metric Tons Per Annum):** | **1377167** |
| | **Bottom ash MTPA (Metric Tons Per Annum):** | **388259** |
| 14 | **Capacity of dry fly ash storage silo(s) (Metric Tons) :** | HCSD SILOS: 1500 (500 x 3)<br>FLY ASH SILOS: 4000 (1000 x 4)<br>**Total Capacity: 5500** |
| 15 | **Details of utilisation of current ash generated during reporting period-** | |
| a | **Total quantity of current ash utilised (MTPA) during reporting period:** | **2105216** |
| b | **Quantity of fly ash utilised (MTPA):** | |
| i | ***Fly ash based products (bricks or blocks or tiles or fibre cement sheets or pipes or boards or panels)*** | **39021** |
| ii | ***Cement manufacturing:*** | **1075132** |
| iii | *Ready mix concrete:* | Nil |
| iv | *Ash and Geo-polymer based construction material:* | Nil |
| v | *Manufacturing of sintered or cold bonded ash aggregate:* | Nil |
| vi | ***Construction of roads, road and fly over embankment:*** | **427088** |
| vii | *Construction of dams:* | Nil |
| viii | *Filling up of low lying area:* | Nil |
| ix | *Filling of mine voids:* | Nil |
| x | *Use in overburden dumps:* | Nil |
| xi | *Agriculture:* | Nil |
| xii | *Construction of shoreline protection structures in coastal districts;* | Nil |
| xiii | *Export of ash to other countries:* | Nil |
| xiv | *Others (please specify):* | Nil |
| c | **Quantity of bottom ash utilised (MTPA):** | Nil |
| i | *Fly ash based products (bricks or blocks or tiles or fibre cement sheets or pipes or boards or panels):* | Nil |
| ii | *Cement manufacturing:* | Nil |
| iii | *Ready mix concrete:* | Nil |
| iv | *Ash and Geo-polymer based construction material:* | Nil |
| v | *Manufacturing of sintered or cold bonded ash aggregate:* | Nil |
| vi | ***Construction of roads, road and flyover embankment:*** | **564052** |
| vii | *Construction of dams:* | Nil |
| viii | *Filling up of low lying area:* | Nil |
| ix | *Filling of mine voids:* | Nil |
| x | *Use in overburden dumps:* | Nil |
| xi | *Agriculture:* | Nil |
| xii | *Construction of shoreline protection structures in coastal districts:* | Nil |
| xiii | *Export of ash to other countries:* | Nil |
| xiv | *Others (please specify):* | Nil |
| | Total quantity of current ash Unutilised (MTPA) during reporting period: | **Nil** |
| 16 | **Percentage utilisation of current ash generated during reporting period (per cent):** | **119.25** |
| 17 | **Details of disposal of ash in ash ponds** | |
| a | Total quantity of ash disposed in ash pond(s) (Metric Tons) as on 31st March (excluding reporting period): | **1073688** |

| | | |
|---|---|---|
| b | Quantity of ash disposed in ash pond(s) during reporting period (Metric Tons): | **Nil** |
| c | Total quantity of water consumption for slurry discharge into ash ponds during reporting period ($m^3$): | **4136715** |
| d | **Total number of ash ponds:** | **1 Ash pond (with 03 Lagoons)** |
| i | ***Active:*** | **1** |
| ii | *Exhausted (yet to be reclaimed):* | Nil |
| iii | *Reclaimed:* | Nil |
| e | **Total area under ash ponds (ha):** | **132** |
| **18** | **Individual ash pond details**<br>***Ash pond-1,2, etc (please provide below mentioned details separately, if number of ash ponds is more than one)*** | |
| a | Status: Under construction or Active or Exhausted or Reclaimed | **Active** |
| b | Date of start of ash disposal in ash pond (DD/MM/YYYY or MMYYYY): | **01/08/2019** |
| c | Date of stoppage of ash disposal in ash pond after completing its capacity (DD/MM/YYYY or MM/YYYY): (Not applicable for active ash ponds) | NA |
| d | Area (hectares): | **132** |
| e | Dyke height (m): | **Variable height 15-18 m** |
| f | Volume ($m^3$): | **5990000** |
| g | **Quantity of ash disposed as on 31st March (Metric Tons):** | **2105216** |
| h | **Available volume in percentage (percent) and quantity of ash can be further disposed (Metric Tons):** | **88.31 % and 6311050 MT** |
| i | Expected life of ash pond (number of years and months): | **03 Years** |
| j | Co-ordinates (Lat and Long): (please specify minimum 4 co-ordinates) | **22°04'36.8"N 75°50'52.2"E**<br>**22°04'26.4"N 75°49'59.9"E**<br>**22°04'42.4"N 75°50'18.2"E**<br>**22°04'20.3"N 75°50'23.6"E** |
| k | Type of lining carried in ash pond: HDPE lining or LDPE lining or clay lining or No lining | **L1-HCSD: Fly ash lining**<br>**L2-BA & L3-BA: Bentonite clay lining** |
| l | Mode of disposal: Dry disposal or wet slurry (in case of wet slurry please specify whether HCSD or MCSD or LCSD) | **Wet and HSCD mode of disposal** |
| m | Ratio of ash: water in slurry mix | **HCSD-55:45 & BA-20:80** |
| n | Ash water recycling system (AWRS) installed and functioning: Yes or No | Yes |
| o | Quantity of wastewater from ash pond discharged into land or water body (m3): | Nil |
| p | Last date when the dyke stability study was conducted and name of the organisation who conducted the study: | **15.12.2021 by IIT-Hyderabad**<br>**18.03.2024 by SGITS-Indore (Annual Certification)** |
| q | Last date when the audit was conducted and name of the organisation who conducted the audit: | NA |
| **19** | **Quantity of legacy ash utilised (MTPA):** | |
| i | *Fly ash based products (bricks or blocks or tiles or fibre cement sheets or pipes or boards or panels):* | NA |
| ii | *Cement manufacturing:* | NA |
| iii | *Ready mix concrete:* | NA |
| iv | *Ash and Geo-polymer based construction material:* | NA |
| v | *Manufacturing of sintered or cold bonded ash aggregate:* | NA |
| vi | *Construction of roads, road and flyover embankment:* | NA |
| vii | *Construction of dams:* | NA |
| viii | *Filling up of low lying area:* | NA |
| ix | *Filling of mine voids:* | NA |
| x | *Use in overburden dumps:* | NA |
| xi | *Agriculture:* | NA |
| xii | *Construction of shoreline protection structures in coastal districts;* | NA |
| xiii | *Export of ash to other countries:* | NA |
| xiv | *Others (please specify):* | NA |

| **20** | **Summary:** | | | |
|---|---|---|---|---|
| | Details | Quantity generated (MTPA) | Quantity utilised (MTPA) and (per cent) | Balance quantity (MTPA) |
| | Current ash during reporting period | **1765426** | **2105216 & 119.25%** | **0** |
| | Legacy ash | 0 | 0 | 0 |
| | **Total** | **1765426** | **2105216 & 119.25%** | **0** |

| | | |
|---|---|---|
| 21 | **Any other information:**<br>**Soft copy of the annual compliance report, and shape files of power plant and ash ponds may be e-mailed to:- moefcc-coalash@gov.in** | Noted |
| 22 | **Signature of Authorised Signatory** | Priyabrata Mondal<br>PRIYABRATA MONDAL<br>AGM(Ash Management)<br>NTPC LIMITED<br>KHARGONE SUPER THERMAL POWER STATION<br>Distt. Khargone 451114(M.P.) |

Annexure-6

एनटीपीसी NTPC

एन टी पी सी लिमिटेड
(भारत सरकार का उद्यम)
NTPC Limited
(A Govt. of India Enterprise)

Ref: KGN/EMG/MPPCB/Ann. Returns

दिनांक-07/05/2024

**प्रति,**

**श्रीमान सदस्य सचिव**
मध्य प्रदेश प्रदूषण नियंत्रण बोर्ड
ई-5, अरेरा कॉलोनी, पर्यावरण परिसर,
भोपाल – 462016, मध्य प्रदेश
(Email- ms-mppcb@mp.gov.in)

**विषय : वित्तीय वर्ष 2023-24 का पर्यावरणीय प्रतिवेदन (फार्म-V) प्रस्तुत करने हेतु।**

महोदय,

एन. टी. पी. सी. लिमिटेड.- खरगोन सुपर थर्मल पावर प्रोजेक्ट द्वारा, वित्तीय वर्ष 2023-24 सम्बद्ध, वार्षिक पर्यावरणीय प्रतिवेदन, निर्धारित फार्म-V अनुसार आपके अनुमोदन हेतु प्रस्तुत है।

वार्षिक पर्यावरणीय प्रतिवेदन म प्र प्र नि बोर्ड के एक्स जी एन पोर्टल पर भी अपलोड कर दिया गया हैं।

सधन्यवाद,

(आशीष कुमार अग्रवाल )
**अपर महाप्रबंधक (राख़ एवं पर्यावरण प्रबंधन)**

**संलग्न:**
1. पर्यावरणीय प्रतिवेदन (फार्म-V), वित्तीय वर्ष 2023-24

**प्रतिलिपि:**
1. क्षेत्रीय अधिकारी, म. प्र. प्र. नि. बो., इंदौर, मध्य प्रदेश (Email-ropcb-indore@mp.gov.in)
2. सदस्य सचिव, के. प्र. नि. बो., दिल्ली (Email-mscb.cpcb@nic.in)
3. क्षेत्रीय कार्यालय, पर्यावरण, वन और जलवायु परिवर्तन मंत्रालय, भोपाल, मध्य प्रदेश (Email-rowz.bpl-mef@nic.in)

# Annual Environment Statement

## FORM – V

(See rule 14)

## Environmental Statement for the Financial year ending the 31st March 2024

### PART – A

| | | | |
|---|---|---|---|
| 1 | Name & address of the Owner/ Occupier of the Industry, operation or process. | **Shri. Subhasis Bose (Chief General Managaer)** | |
| | | **NTPC Ltd. Khargone Super Thermal Power Project** | |
| | | Vill.-Selda, Teh.-Barwah, | |
| | | Dist.-Khargone, Madhya Pradesh, PIN-451114 | |
| 2 | Industry category Primary (STC Code), Secondary (STC Code) | - | |
| 3 | Production Capacity- Units | 1320 MW (2 x 660 MW) | |
| 4 | Year of establishment | | Date of Commissioning |
| | | Unit-I | 29/9/2019 |
| | | Unit-II | 24/3/2020 |
| 5 | Date of last environmental statement | 01-07-2023 | |

### PART – B

**Water & Raw material Consumption**

**1 Water Consumption m3/day process**

| | During the previous financial year 2022-23 | During the current financial year 2023-24 |
|---|---|---|
| Cat-I: Industrial Cooling | 34983 | 43532 |
| Cat-I: Boiler feed | 826 | 850 |
| Cat-I: Process-Ash Water | 5381 | 2080 |
| Cat.II: Domestic | 1084 | 1080 |
| Cat-III: Process-water polluted,pollutants easily biodegradable | 176 | 168 |

**Water consumption per unit of products (m3/mwhr)**

| Name of Products | During the previous financial year 2022-23 | During the current financial year 2023-24 |
|---|---|---|
| Electricity | 2.76 | 2.27 |

**2 Raw Material Consumption**

| Name of Raw Materials | Name of Products | Consumption of Raw Material Per unit of output: During the previous financial year 2022-23 | During the current financial year 2023-24 |
|---|---|---|---|
| Coal (kg/kwh) | Electricity | 0.64 | 0.61 |
| Oil (ml/kwh) | | 0.80 | 0.28 |

### PART – C

**Pollution Generated**

(Parameters as specified in the consent issued)

| 1 | Pollutants | Quantity of pollutant discharged * | Concentration of Pollutants in discharges | Percentage of variation from prescribed standard with reasons |
|---|---|---|---|---|
| a | **Water** (Ann. Avg. of ETP treated effluents) (Kg/day) | | | |
| | **pH** (Limit: 5.5-9.0) | Not Quantifiable | 7.4 | Nil |
| | **TSS** (Limit: 100 mg/l max.) | 17.3 | 16.1 mg/l | Nil |
| | **BOD** (Limit: 30 mg/l max.) | 12.2 | 11.3 mg/l | Nil |
| | **COD** (Limit: 250 mg/l max.) | 69.9 | 65 mg/l | Nil |
| | **Oil&Grease** (Limit: 10 mg/l max.) | 4.3 | 4 mg/l | Nil |
| | **TDS** (Limit: 2100 mg/l max.) | 797.8 | 741.7 mg/l | Nil |
| | **Chlorides** (Limit: 1000 mg/l max.) | 165.1 | 153.5 mg/l | Nil |
| | *No water discharged outside plant premises. Treated water reused in ash handling, dust supression, processes etc. | | | |
| b. | **Air** (Ann. Avg. of stack emissions) (MT/Yr.) | | | |
| | **PM** (Limit: 30 mg/nm3 max.) | 528.6 | 24.38 mg/nm3 | Nil |
| | **SO2** (Limit: 100 mg/nm3 max.) | 27775.4 | 1281.36 mg/nm3 | Nil |
| | **NOx** (Limit: 100 mg/nm3 max.) | 6198.9 | 285.97 mg/nm3 | Nil |
| | **Hg** (Limit: 0.03 mg/nm3 max.) | 0.217 | 0.01 mg/nm3 | Nil |

### PART – D

**[as specified under Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016]**

| 1 | Hazardous Wastes | Category | Total Quantity (in MT): During the previous financial year 2022-23 | During the current financial year 2023-24 |
|---|---|---|---|---|
| a. | From Process | | | |
| | Used or Spent Oil | Sch.-I, Cat.-5.1 | 8.8 MT | Nil |

| | | | | |
|---|---|---|---|---|
| | Wastes or residues containing oil | Sch.-I, Cat.-5.2 | Nil | Nil |
| | Spent ion exchange resin containing toxic metals | Sch.-I, Cat.-35.2 | Nil | Nil |
| | Empty barrels/containers/liners contaminated with hazardous chemicals /wastes | Sch.-I, Cat.-33.1 | 7.45 MT | 12.14 MT |
| b. | From Pollution Control Facilities | | Nil | Nil |

**PART – E**

**Solid Wastes**

| 1 | **Solid Wastes** | | **Total Quantity (in MT)** | |
|---|---|---|---|---|
| | | | **During the previous financial year 2022-23** | **During the current financial year 2023-24** |
| a. | From Process | Ash Generation | 1309698 | 1765426 |
| b | From pollution control facility | | Nil | Nil |
| c | Quantity recycled or re-utilized. | Ash Utilisation | | |
| | Fly ash issue to Cement Plants | | 748115 | 1075055 |
| | Fly ash issue to Brick plants & Ash based product manufacterurs | | 1403 | 39021 |
| | Fly ash issue to Others-Traders | | 0 | 0 |
| | Pond ash to Road Projects | | 594997 | 991140 |
| | Pond ash in Ash dyke stabilisation | | 0 | 0 |
| | Pond ash to Cement Plants | | 0 | 0 |
| | Pond ash to Brick plants & Others | | 0 | 0 |
| | | **Total** | **1344515** | **2105216** |

**PART – F**

**Please specify the characteristics (in terms of concentration and quantum) of Hazardous as well as solid wastes and indicate disposal practice adopted for both these categories of wastes.**

| 1 | **Hazardous Wastes** | **Composition** | **Quantum (Sanctioned) MT** | **Mode of disposal practice** |
|---|---|---|---|---|
| | Used or Spent Oil (Sch.-I, Cat.-5.1) | - | 70 | Sell to recycler registered with CPCB/SPCB |
| | Wastes or residues containing oil (Sch.-I, Cat.-5.2) | - | 10 | Sell to authorised reprocessors/ recycler registered with CPCB/SPCB |
| | Spent ion exchange resin containing toxic metals (Sch.-I, Cat.-35.2) | - | 2 | Sell to authorised reprocessors/recycler registered with CPCB/SPCB Or to be disposed as per SOP published by CPCB |
| | Empty barrels/containers/ liners contaminated with hazardous chemicals /wastes (Sch.-I, Cat.-33.1) | - | 10 | Disposal through registered recycler authorised with SPCB |
| 2 | **Solid Wastes** | **Composition (% by Mass)** | **Quantum of disposal (MT)** | **Mode of disposal** |
| | **Ash** | | 2105216 | Soild waste as ash generated being utilised by issuing to cement plants, bricks & ash based product manufacterurs etc. Balance quantities of un-utilised ash disposed at ash dyke through network of pipelines. |
| | Loss on Ignition | 0.30 | | |
| | SiO2+Fe2O3+Al2O3 | 94.20 | | |
| | Magnesium oxide as MgO | 0.49 | | |
| | Sulphur as SO3 | 0.52 | | |
| | Alkalies as Sodium Oxide Na2O | 0.48 | | |
| | Chlorides | 0.01 | | |
| | Others | 4.00 | | |

**PART – G**

**Impact of pollution control measures on conservation of natural resources and consequently on the cost of production**

Pollution control and environment management measures adopted has resulted in general improvement in the quality of environment in and around the industry. In turn the cost of production generally increases but improves the quality of environment in the way of betterment for people, flora and fauna, are incomparable.

| | **Pollution Control & Environmmet Management Measures** | **Cost Expenditure in 2023-24 (Rs. Lakhs)** |
|---|---|---|
| 1 | Greenbelt development & Afforestation works | 213.8 |

| | | |
|---|---|---|
| 2 | Environment monitoring works | 4.14 |
| 3 | Hydrogelogy review study | 17.07 |
| 4 | Environment awareness & Other Envt. Expenditures | 4.56 |
| | **Total** | **239.56** |

**PART – H**

**Additional investment proposal for environmental protection including abatement of pollution**

**Installation of FGD:** Installation & Commissioning of Flue Gas De-sulfurisation plants for both units for the control of S0x emissions from stacks at an cost of Rs.68286.9 Lakhs

**PART – I**

**Miscellaneous**

**Any other particulates in respect of environment protection and abatement of pollution.**

| | |
|---|---|
| 1 | **Tree Plantation:**<br>1. Cummulative 4.35 Lakh trees planted under Greenbelt/Roadside/Carbon Sink plantation inside and around project. |
| 2 | **Ash Utilisation:**<br>1. Complied 100% Ash Utilisation in FY 2023-24 i.e. 119.25 % |

**(Ashish Kumar Agarwal)**
**AGM (Ash & Envt. Mgmt.)**
**Auth. Signatory**

**ANNEXURE-7**

# FGD Progress Status at NTPC-Khargone Super Thermal Power Project

| S. No. | Description | Status as on as on March'2024 |
|---|---|---|
| 1. | **Package description** | Awarded to M/s L&T Ltd. on 31-07-2018 |
| 2. | **Status of Front Handover** | All the work front required to complete the entire scope of civil & architectural works had been handed over to L&T. |
| 3. | **Total Excavation** | Completed |
| 4. | **U#1 RCC & Common facilities** | 28866 / 28866 Cu. m. Completed |
| 5. | **U#2 RCC** | 9315/ 9315 Cu. m Completed |
| 6. | **Structure Erection U#1** | 5431 / 5431 MT Completed<br>All the erection works pertaining to Unit-1 & common facilities are Completed |
| 7. | **Structure Erection U#2** | 5431 / 5431 MT Completed<br>All the erection works pertaining to Unit-2 are Completed |
| 8. | **U#1 & 2 Chimney shell** | Chimney Unit-1 and 2 all work Completed |
| 9. | **Date of Commercial Operation** | U#1:- 25.05.2023<br>U#2:- 08.12.2023 |

**Photographs:**

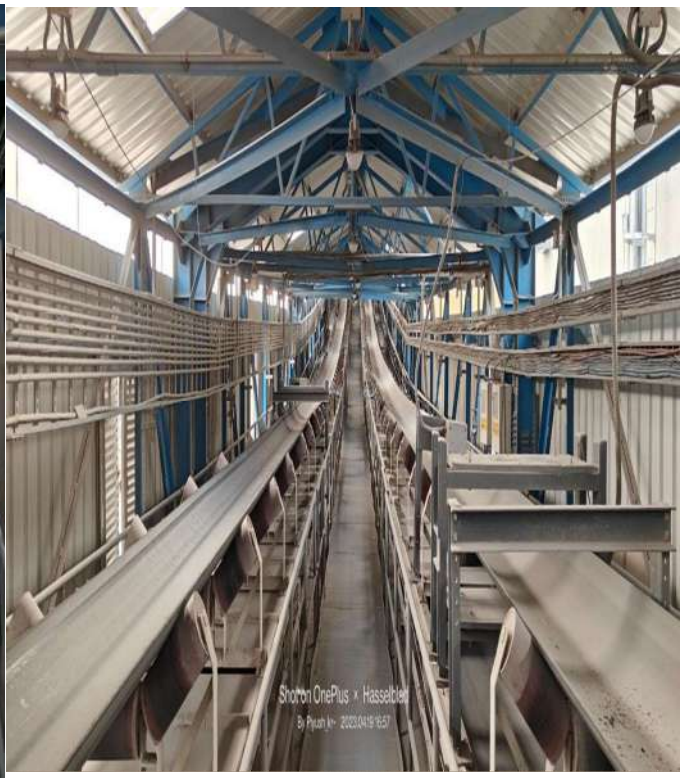
## FGD Overview

## DM and Process Water

## Unit # 1 Absorber


## Wet Ball Mill A and B

## Lime Stone Conveyor

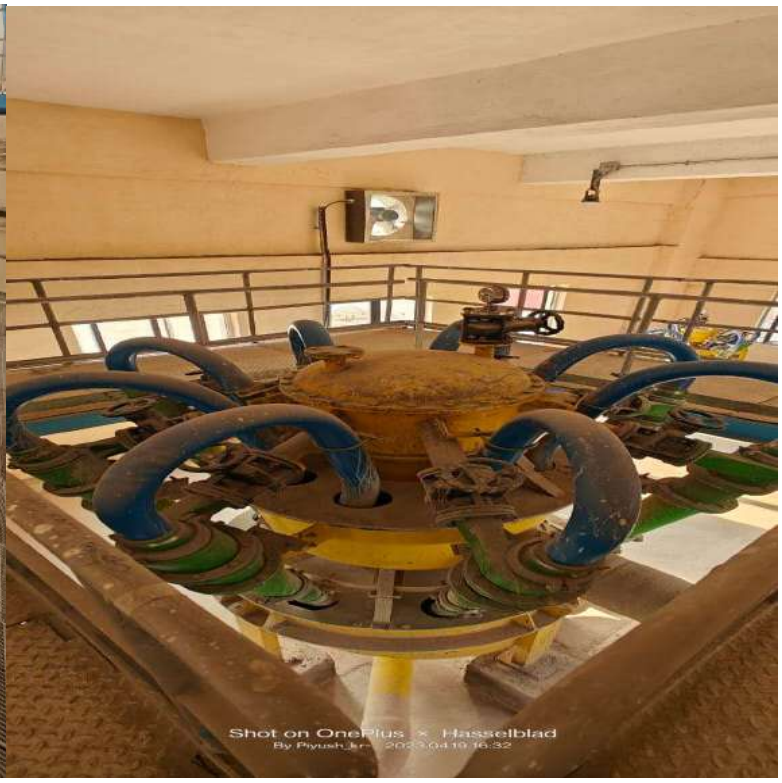


## Lime Stone Silo

## Lime Stone Truck Tippler


## Lime Stone Slurry Tank

## Gypsum Conveyor




## Gypsum Storage

**ANNEXURE-8**

# Water withdrawal data at NTPC-Khargone STPS from Omkareshwar Dam on Narmada River

## FY: 2023-24

| Water withdrawal data at NTPC Khargone STPP from Omkareshwar Dam on Narmada River | | | | |
|---|---|---|---|---|
| **Month** | **Start date** | **Finish date** | **Days** | **Water Drawn, M3** |
| **Apr-23** | 01-04-2023 | 30-04-2023 | 30 | 1912219 |
| **May-23** | 01-05-2023 | 31-05-2023 | 31 | 1688021 |
| **Jun-23** | 01-06-2023 | 30-06-2023 | 30 | 1336695 |
| **Jul-23** | 01-07-2023 | 31-07-2023 | 31 | 818720 |
| **Aug-23** | 01-08-2023 | 31-08-2023 | 31 | 1711868 |
| **Sep-23** | 01-09-2023 | 30-09-2023 | 30 | 1411870 |
| **Total Water Drawn, M3** | | | | **8879393** |

| Water withdrawal data at NTPC Khargone STPP from Omkareshwar Dam on Narmada River | | | | |
|---|---|---|---|---|
| **Month** | **Start date** | **Finish date** | **Days** | **Water Drawn, M3** |
| **Oct-23** | 01-10-2023 | 31-10-2023 | 30 | 2029359 |
| **Nov-23** | 01-11-2023 | 30-11-2023 | 31 | 1880364 |
| **Dec-23** | 01-12-2023 | 31-12-2023 | 30 | 1472120 |
| **Jan-24** | 01-01-2024 | 31-01-2024 | 31 | 1457214 |
| **Feb-24** | 01-02-2024 | 29-02-2024 | 29 | 1651797 |
| **Mar-24** | 01-03-2024 | 31-03-2024 | 31 | 1707497 |
| **Total Water Drawn, M3** | | | | **10198351** |

**Total Water Withdrawal for FY: 2023-24- 19077744 m3**